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INVESTIGATION OF THE EFFECTS OF EXTERNAL CURRENT SYSTEMS ON THE MAGSAT DATA USING GRID CELL MODELING TECHNIQUES

SUBMITTED BY

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16. Abstract

The overall objective of this effort in support of the Magsat (Magnetic Fields Satellite) project has been to investigate the feasibility of modeling magnetic fields due to certain electrical currents flowing in the earth's ionosphere and magnetosphere. A new method was devised to carry out forward modeling of the magnetic perturbations that arise from space currents. The procedure utilizes a linear current element representation of the distributed electrical currents. The finite thickness elements are combined into loops which are in turn combined into cells having their base in the ionosphere. In addition to the extensive field modeling, additional software was developed for the reduction and analysis of the Magsat Data in terms of the external current effects. Direct comparisons between the models and the Magsat data are possible.

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CONTRACT FINAL REPORT

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I. INTRODUCTION

The overall goal of this investigation has been to study the feasibility of modeling the magnetic fields produced by certain electrical currents flowing in the earth's ionosphere-magnetosphere system. Vector magnetic field measurements from the near-polar orbiting Magsat satellite contain, in addition to the main geomagnetic field and crustal anomaly fields, contributions that arise from these external currents. In fulfilling the ultimate goals of the Magsat project, it is desirable that the external current effects be identified in the observations and subsequently separated from the internal field. The objective of this investigative effort has been to determine the capability of a modeling procedure to facilitate the separation of these external and internal components.

The approach of this feasibility study was to develop forward modeling procedures through which the magnetic effects of model currents may be derived. It is intended to enable the modeling of, separately, the equatorial electrojet, S_q currents, and the effects due to auroral zone and polar cap currents including the high latitude ionosphere-magnetosphere coupling currents. Candidate current systems were devised and resulting 'typical' magnetic field signatures calculated for comparison with Magsat observations.

The effort has successfully demonstrated that an efficient, computationally economical, yet accurate, model of the magnetic effects of distributed space currents could be developed.

II. PROJECT EVOLUTION

A. Historical Perspectives

Prior to the Magnetic Fields Satellite (MAGSAT), previous satellite measurements of near-earth vector magnetic fields had been severely limited, both in number and in quality. The Navy TRIAD satellite carried a tri-axial magnetometer into a near earth-polar orbit at 800 km. A number of investigators have used the TRIAD data in studying the signatures of high latitude field-aligned currents (Armstrong and Zmuda, 1970, 1973; Zmuda and Armstrong, 1974; Iijima and Potemra, 1976a,b, 1978; Sugiura and Potemra, 1976). Due to a relatively poor knowledge of the spacecraft attitude, however, TRIAD data has not been of significance for detailed modeling of the earth's main magnetic field.

At the time of Magsat, magnetic field observations made from the ISIS-2 satellite were also being successfully employed to study high latitude perturbations associated with the Birkeland currents (Klumpar et al, 1976; Burrows et al., 1976; McDiarmid et al., 1977, 1978). Deviations on the order of 1000 nT in the component transverse to the main field are not uncommon in the Birkeland current regions. The ISIS data is unique by virtue of the fact that direct comparisons of magnetic perturbations with charged particle and plasma observations are being made simultaneously from a single satellite (Klumpar et al., 1976). Results of these comparisons illustrate that the magnetic signatures attributed to Birkeland currents are not always unique to locations where auroral particle precipitation is present (Klumpar, 1976, 1979).

The first near-earth satellite measurements of the earth's global magnetic field usable for providing large scale field models were those of

the Polar Orbiting Geophysical Observatory (POGO) series. These satellites measured only the scalar magnetic field primarly during the last half of the 1960's over an altitude range from 400 km to 1510 km. Several magnetic field models based upon the POGO data had been published. Langel (1974a,b, 1975a,b) carried out a detailed analysis of the POGO scalar magnetic field data at high latitudes. His analysis shows that there are extended regions over which the field is enhanced or depressed with respect to the model magnetic field. These variations can only partially be interpreted in terms of horizontal ionospheric currents. Magnetospheric current systems undoubtedly produce an important contribution to these field variations, and would be no less important in the MAGSAT data.

The MAGSAT mission would represent the first time U.S. scientists would have access to detailed, accurate vector magnetic fields from a near-earth orbiting satellite.

B. Proposed Investigation

In response to NASA's Announcement of Opportunity from the Office of Space and Terrestrial Applications (A.O. No. OSTA 78-1) dated September 1, 1978 for "Data Use Investigations for the Magnetic Fields Satellite (MAGSAT) Mission" a proposal was submitted from the University of Texas at Dallas in January, 1979. The proposed study, entitled "Investigation of the Effects of External Current Systems on the MAGSAT Data Utilizing Grid Cell Modeling Techniques" under the direction of Dr. David M. Klumpar, of UT-Dallas as Principal Investigator, and Drs. Jerry L. Kisabeth (Univ. of Alberta) and Walter J. Heikkila (UT-Dallas) as co-investigators, was to be performed during the period from 1 September, 1979 through 31 August, 1981. This original proposal had the following broad objective:

To apply a modeling procedure to the vector MAGSAT data in order to separate the terrestrial component from that due to extraterrestrial sources. The proposed study would contribute to the MAGSAT program objectives in two ways:

i) Provide removal of those contributions to the measured field that are undesirable for studies of the main core field and localized crustal variations.

ii) Provide detailed accurate vector measurements of the field due to ionospheric and magnetospheric currents for the purpose of studying these current systems.

The proposed study was an ambitious one, involving 3.6 scientific man-years of effort at a proposed cost of $196,000 in January, 1979 dollars. As originally proposed this effort had two major parts. The first part of this proposed investigation was to model the effects of the various external current systems (including induced currents in the earth) at observation positions relevant to the MAGSAT satellite orbit in order to ascertain whether or not the fields due to external sources may be removed from the MAGSAT data with any degree of accuracy. The second part of that proposed investigation was the application of the resulting modeling techniques to the MAGSAT data by taking into account the state (temporal and spatial variations) of the external current systems at the time the data was recorded. The investigation would be a natural extension of magnetic field modeling techniques under development for a number of years at the University of Alberta, Edmonton, Canada, and the Texas A. and M. University at College Station, Texas (see Kisabeth, 1975, Kisabeth and Rostoker, 1977). Those modeling techniques have been successfully used in the

modeling of magnetic field measurements from many sources including ground-based magnetometer arrays in northern Canada and in Scandinavia (Oldenburg, 1976; Kisabeth and Rostoker, 1977; Hughes and Rostoker, 1979; Bannister and Gough, 1978), high latitude total field variations (ΔB) from the OGO 2, 4, and 6 satellites, and vector field component measurements from polar orbiting satellites ISIS-2 and TRIAD.

In its original form, the concept of the investigation included extensive detailed modeling as well as direct application to the reduction of MAGSAT data.

The first part of the proposed research would deal primarily with the development of modeling programs necessary to predict magnetic field perturbations at MAGSAT orbital altitudes due to external current systems (and induced currents in the earth). These external current systems may be subdivided into the following categories for study:

i. S_q current system and the equatorial electrojet.

ii. Auroral zone and polar cap current systems along with ionospheric-magnetospheric coupling currents (e.g., Region 1 and 2 field aligned currents, polar electrojets, currents associated with magnetospheric convection).

iii. Ring current (asymmetries in the ring current could also be included in category (ii)).

iv. Bow shock, magnetosheath, magnetopause and magnetotail currents.

The effects of induction in the conducting earth due to time variations of the external systems could be treated by assuming the earth

to be infinitely conducting below a given depth. This model has worked especially well for substorm current systems (see Kisabeth, 1975). A more realistic conductivity structure would be extremely difficult to include with sources as complex as the current systems given above (Mareschal and Kisabeth, 1977).

After suitable computer programs had been developed for current systems in each of the categories above, a detailed study was proposed to determine the magnetic signatures of each current system along the MAGSAT orbit for varying degrees of magnetic activity.

The second part of this proposed research was the application of the results of the modeling study to MAGSAT data reduction, the main goal being to see if contributions from the various external current systems can be systematically identified and thus removed from the magnetometer data. The degree to which this can be done would provide valuable information concerning the accuracy of the reduced data set which is to be used to study the main field and crustal anomalies.

The UT-Dallas proposal was provisionally accepted on July 5, 1979, for negotiation as one of the investigations to be performed using data from the MAGSAT mission.

C. The Descoping Phase

During the seven months following provisional acceptance, the UT-Dallas proposal proceeded through the so-called negotiation stage, during which a draft statement of work was prepared and circulated. Also, during this 1-year period following proposal submission one of the proposed co-investigators (J. L. Kisabeth) assumed a position with industry outside of the space science research stream. This necessitated his withdrawal

from the project as a direct active participant in its development. Because of his acknowledged expertise in the field and the recognized value of his advice we sought and received from his new employer consent to utilize his expertise as an informal consultant if only on a very limited basis.

Shortly thereafter UT-Dallas was informed that there had been severe cutbacks in investigatory funding and that the UT-Dallas proposed effort was being reduced to that of a "feasibility study". By the end of January, 1980, a new statement of work had been drafted by NASA and accepted by the P.I. It represented only a small fraction of the level of effort that was deemed necessary for a full treatment of the important problem of external current effects on low-altitude magnetic measurements. Still the delays continued. Active negotiation of the contract was held in limbo between February and August of 1980. During these seven very frustrating months conflicting reports were received that only some or even none of the Magsat investigations might receive funding. Finally in September of 1980; two years after the initial Magsat Investigations Announcement of Opportunity; eleven months after the MAGSAT launch; and 3 months after satellite reentry the UT-Dallas contract was funded. The final contract called for 0.7 scientific man-years of effort in comparison to the proposed 3.6 man-years and was funded at $64,000, a reduction by more than two-thirds of that initially proposed.

D. Final Statement of Work

The Statement of Work consists of the objective to be satisfied by the effort, the approach to be used in satisfying the objective, and the tasks required to satisfy it. For Magsat investigation M-013, the Statement of Work is as follows:

Objective:

The objective of this effort is to perform a feasibility study of a modeling procedure to Magsat data to separate the terrestrial component from that due to extraterrestrial sources.

Approach:

The investigator shall perform a feasibility study of modeling programs necessary to predict magnetic field perturbations at Magsat orbital altitudes due to external current systems and induced currents in the Earth. These external current systems will be subdivided into the following categories for study:

a. Sq current systems and the equatorial electrojet

b. Auroral zone and polar cap current systems along with ionospheric-magnetospheric coupling curents (e.g., Region 1 and 2 field-aligned currents, polar electrojects, currents associated with magnetospheric convection)

c. Ring current (asymmetries in the ring current will also be included in category b.

d. Bow shock, magnetosheath, magnetopause and magnetotail currents. The effects of induction in the conducting Earth due to time variations of the external systems shall be treated by assuming the Earth to be infinitely conducting below a given depth.

Because the software developed under this contract may be important to the ability of other Magsat investigators in separating external fields from anomaly fields, all results, including software and documentation, are to be made available (pre-publication) to other investigators via the Magsat Project Scientist. This insure that the cooperative scientific effort described in Task d (below) will be fulfilled.

Tasks:

The following tasks shall be performed by the investigator in fulfillment of the above objectives:

a. Obtain and render operable, existing software developed by Dr. Kisabeth.

b. Extend the capability of software, as required, to enable modeling of:

(1) The Sq current system and equatorial electrojet, and
(2) Auroral zone and polar cap current systems along with ionospheric-magnetospheric coupling currents.

c. Utilize the software to derive "typical" magnetic signatures of these current systems for local times pertinent to the Magsat orbit.

d. Compare these signatures to signatures derived from Magsat data. This should be carried out cooperatively with other Magsat investigators (e.g., the U.S. Geological Survey, Dr. Potemra, Dr. Burrows).

e. Prepare and submit to NASA periodic progress reports and a detailed final report documenting the results of this investigation.

III. ACCOMPLISHMENTS (RESULTS)

The overall accomplishment of this investigation has been the development of a new modeling technique that accurately determines the vector magnetic field that would arise from electrical currents distributed throughout the near-earth space environment. The modeling procedure has been applied specifically to the terrestrial high latitude ionospheric currents and to the ionosphere-magnetosphere coupling currents to ascertain their contributions to the magnetic fields measured by high latitude ground-based magnetometer arrays and to the field perturbations observed from low altitude polar orbiting satellites. The principles of the modeling technique are general and may readily be applied to other distributed current systems found in the ionosphere and in the magnetosphere. The model was used to derive typical magnetic signatures of these high latitude currents and was applied specifically to Magsat orbits for direct comparison with empirically determined magnetic perturbations derived from the Magsat data. To support these comparisons considerable effort was also expended under this contract to develop software for the reduction of Magsat data to produce the empirical magnetic perturbations. The following paragraphs describe, in detail, the accomplishments under the two categories of Magsat data reduction and Field Modeling.

A. Magsat Data Reduction

Although the primary goal of this contract was to develop field modeling techniques for the near-earth magnetic field arising from external currents, such development cannot successfully be carried out without concomitant study and analysis of the actual Magsat Data. The following

paragraphs describe the Magsat data reduction efforts carried out at UT-Dallas under this contract.

The initial Magsat data reduction program was developed to read the Magsat Chronicle format data tapes on a U.T.D. PDP 11/45 computer. The capability to read the Chronicle tapes and printout either the orbital data alone or both orbital and magnetic field-values from both scalar and vector magnetometers for any specified time period contained on the source tape was the first step to accessing the Magsat data. The program computes geodetic longitude and latitude, and altitude of the spacecraft and outputs this information along with inertial and magnetic coordinate positions. The magnetic field observations during each second are scanned with maximum, minimum, and average values for each scalar head and each vector component being printed at one second intervals. This software package formed the basis of additional data reduction software that stores selected portions of Magsat data on magnetic disk. Additional data reduction software was then developed to access the stored data, subtract a spherical harmonic model field, and plot each of the three resultant magnetic component deviations and the scalar field difference on a high resolution interactive vector graphics terminal.

The graphics capability for visualizing the Magsat observations as deviations with respect to a spherical harmonic main field model is illustrated in the accompanying figures. Figure 1 shows from top to bottom the deviations in the North, East, Vertical components, and the scalar magnitude deviation with respect to the MGST(6/80) spherical harmonic field model for the Magsat orbit over the northern hemisphere from 10:51 - 11:21 UT on November 13, 1979. The polar dial on the right hand side of the

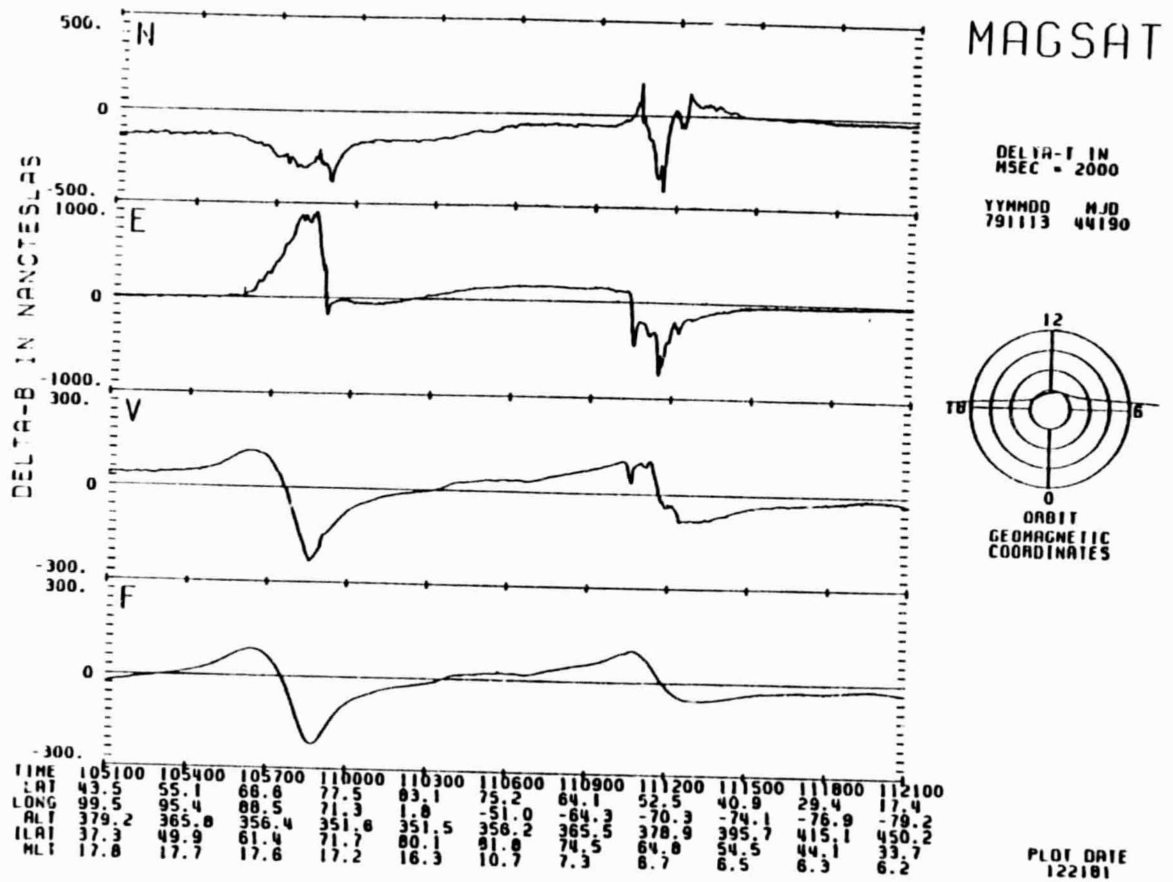

Figure 1

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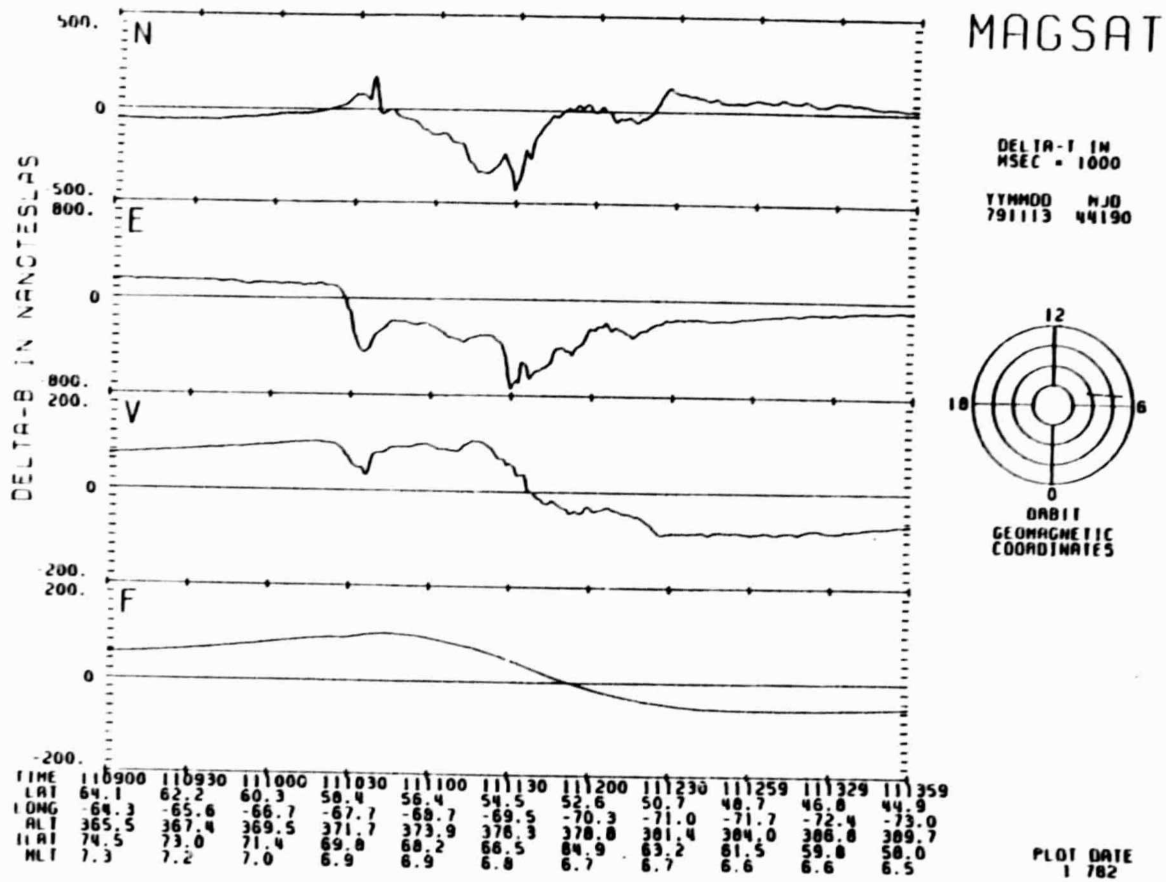

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LONG -64.3 -65.6 -66.7 -67.7 -68.7 -69.5 -70.3 -71.0 -71.7 -72.4 -73.0
ALT 365.5 367.4 369.5 371.7 373.9 376.3 378.8 381.4 384.0 386.8 389.7
MLAT 74.5 73.0 71.4 69.8 68.2 66.5 64.9 63.2 61.5 59.8 58.0
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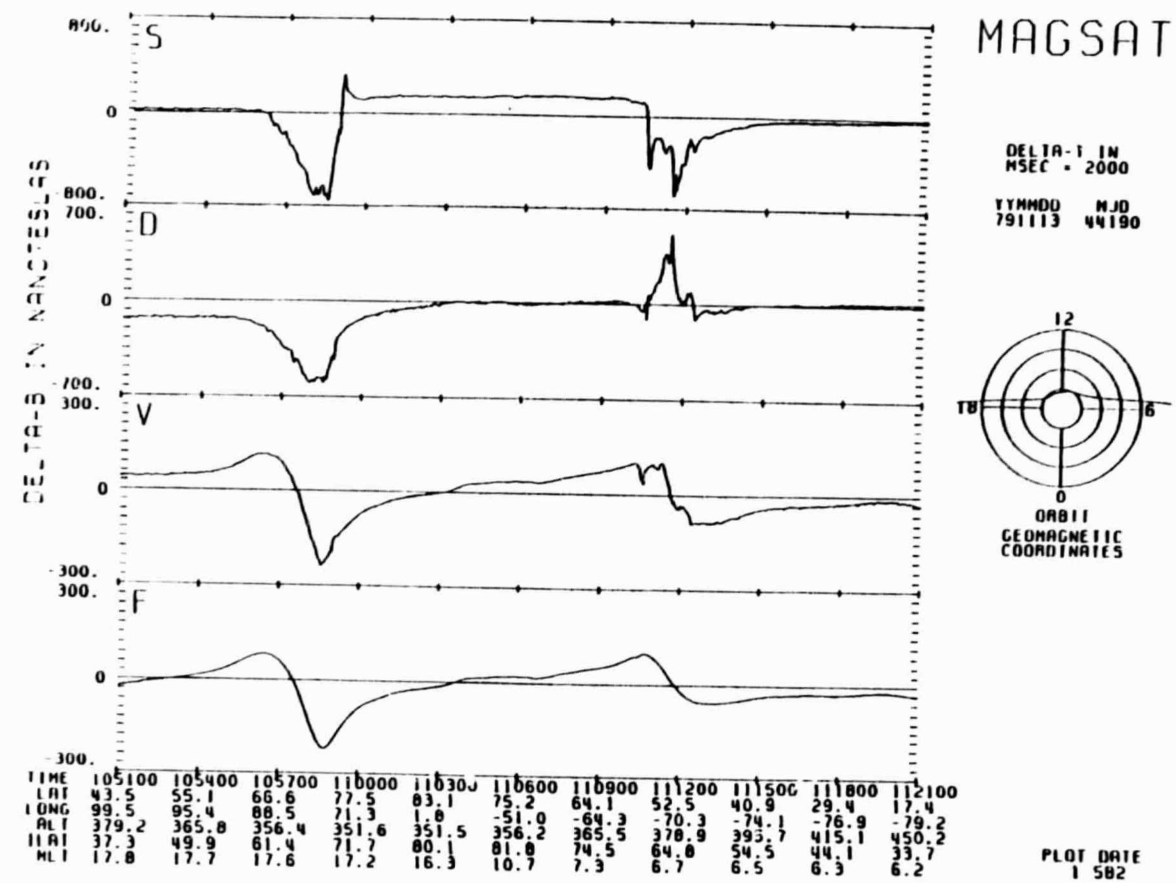
PLOT DATE 1 782

Figure 2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791113 44190
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DELTA-B IN NANOTESLAS
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TIME 105100 105400 105700 110000 110300 110600 110900 111200 111500 111800 112100
LAT 43.5 55.1 66.6 77.5 83.1 75.2 64.1 52.5 40.9 29.4 17.4
LONG 99.5 95.4 88.5 71.3 1.0 -51.0 -64.3 -70.3 -74.1 -76.9 -79.2
ALT 379.2 365.8 356.4 351.6 351.5 356.2 365.5 378.9 393.7 415.1 450.2
MLAT 37.3 49.9 61.4 71.7 80.1 81.0 74.5 64.0 54.5 44.1 33.7
MLT 17.8 17.7 17.6 17.2 16.3 10.7 7.3 6.7 6.5 6.3 6.2
PLOT DATE
1 582

Figure 3

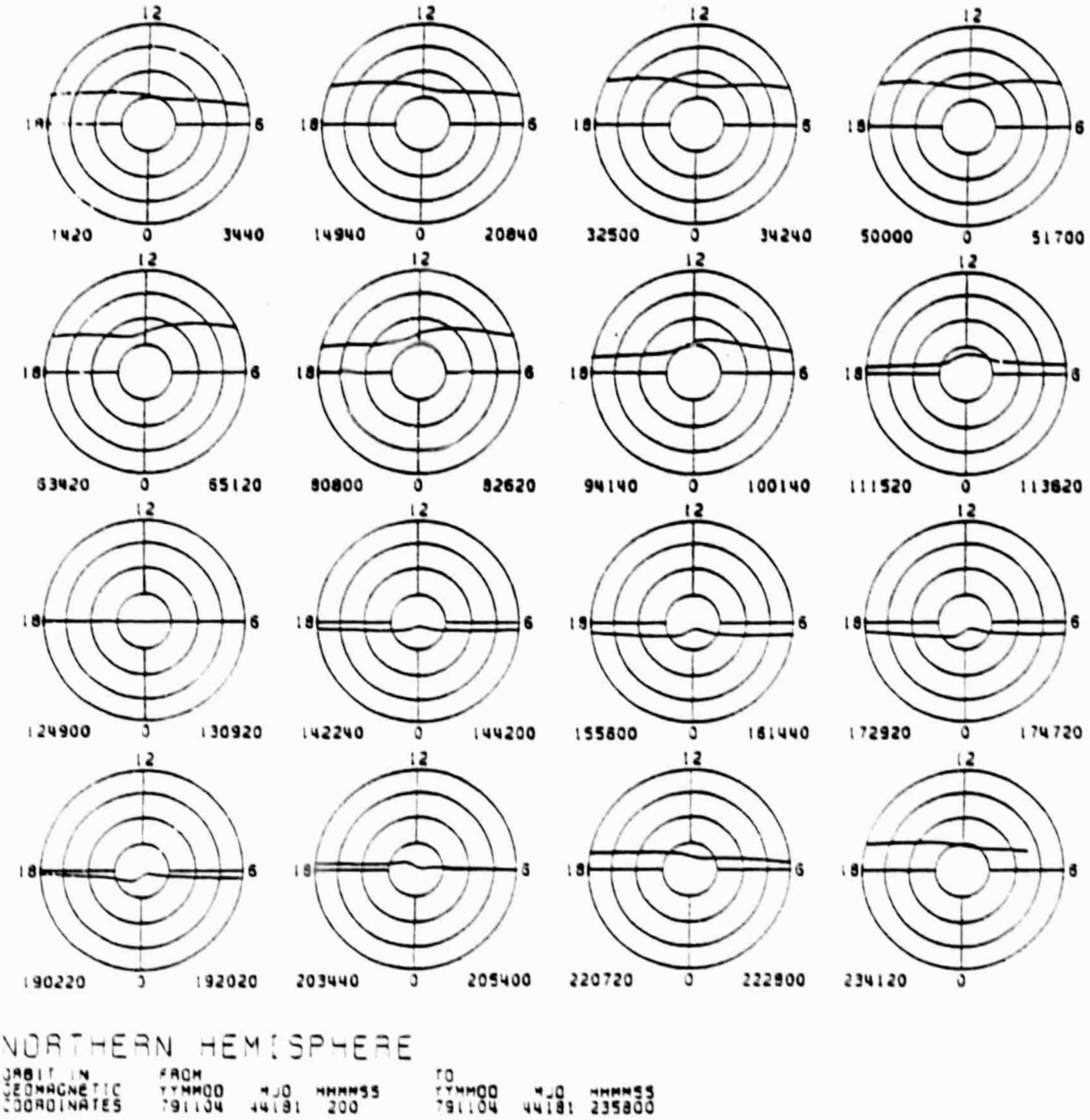
figure depicts the location of the satellite in an Invariant Latitude/Magnetic Local Time coordinate system for reference to the data plot. Perturbations in all three vector components, but particularly in the E-W component, are evident as the satellite passes thorough the Birkeland current system near the dusk and dawn locations of the auroral oval centered near 60° invariant latitude. This plot shows the large-scale features over a 30-minute portion of the orbit with a plotted resolution of two-seconds along the satellite orbit. In order to examine details and finer scale perturbations, the graphics routine developed at UTD has the capability to "home in" on a selected time interval and plot the observations at higher resolution. This capability is illustrated in figure 2 where now only a five-minute portion of the data of figure 1 are presented over that segment of the orbit that crosses the dawn sector of the Birkeland curent system. In this plot the resolution has been increased by a factor of two to one-second along the orbit. A number of small-scale features are now visible on this plot that were unresolved in Figure 1.

It is sometimes useful to view the magnetic perturbations as they would appear in an alternate coordinate system. Figure 3 illustrates the effect of a coordinate transformation to a system in which the field vector is resolved into components along (S) and perpendicular (D) to the earth-sun line. In this coordinate system the polar cap top hat in the sunward-antisunward component of the magnetic field, often attributed to magnetospheric convection, stands out quite clearly as a positive perturbation in the S component at invariant latitudes above 69° . Note in this figure that the D component perturbation at these high latitudes is essentially zero, in sharp contrast to figure 1 in which the polar top hat contributed

about equally to the N and E components.

The desire to visualize, with respect to the auroral oval, the Magsat derived magnetic perturbations along the orbit path has prompted us to develop as a first step, an orbit plotting program. Ultimately this program will be able to display horizontal magnetic perturbation vectors at regular intervals along the satellite orbit. The entire sequence of Magsat orbits in magnetic local time, invariant latitude coordinates over northern latitudes ($>50^o$) is shown in Figure 4 for November 4, 1979. Note that as universal time advances through the day beginning in the upper left plot the orbital path of the satellite progresses across the polar ionosphere from the dayside of the polar cap to the nightside. Those orbits occurring during the first few hours of the day pass through or close to the so-called magnetospheric cusp where there are unique currents. At later universal times (near 1300 UT) the satellite cuts lie along or near the 0600-1800 magnetic meridian where the high latitude current pattern differs from that near the cusp. Later the orbit plane passes on the nightside of the 0600-1800 meridian and then returns to the dayside before midnight. Thus due to the location of the Magsat orbit and to the offset of the Magnetic pole relative to the geographic pole there is a systematic and repeatable 24-hour periodicity in the location of the satellite orbit with respect to the auroral and polar currents.

It follows that there will also be a systematic and repeatable 24-hour pattern in the magnetic perturbation signatures derived from the Magsat data. To demonstrate this repeatability we have selected a sequence of six orbits over the northern high latitudes on each of three different days.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FROM
YYMMDD MJD HHMMSS
791104 44181 200
TO
YYMMDD MJD HHMMSS
791104 44181 235800

Figure 4

Figure 5 illustrates the remarkable similarity between the Magsat orbital paths for similar universal times on each of the three days. The sunward components of the relative magnetic perturbations for each of the 18 passes (two missing) are shown in Figure 6 with the same relative positions as in the previous figure. The day to day similarity of the perturbations on each of the three days during identical universal time periods is apparent as is the consistent change in the character of the perturbation signature with increasing universal time during each day.

During the early hours of the day (02-08 UT) the sunward component perturbations appear to be highly structured with a tendency for a positive perturbation over the center of the polar cap. At later times as the satellite orbit approaches the dawn-dusk magnetic meridian a nearly constant positive top hat develops with steep negative perturbations on either side of the polar cap. The dawn-dusk component of the magnetic field is shown for the same orbits in Figure 7. Again there is a systematic variation with universal time. Near the 0600-1800 meridian the perturbation signature is negative on the afternoon side of the polar cap and positive on the morning side. At later times both sides of the polar oval display negative D-component perturbations.

In addition to addressing the repeatability and overall constancy of the polar external current systems, the significance of these periodic and repeatable patterns lies in their potential effect on crustal anomaly studies. An example will illustrate the problem. Consider a particular region of the earth's surface centered at some intermediate geographic latitude, say at 60° N. The magnetic field attributed to crustal anomalies within this region is determined from magnetic perturbations deduced from

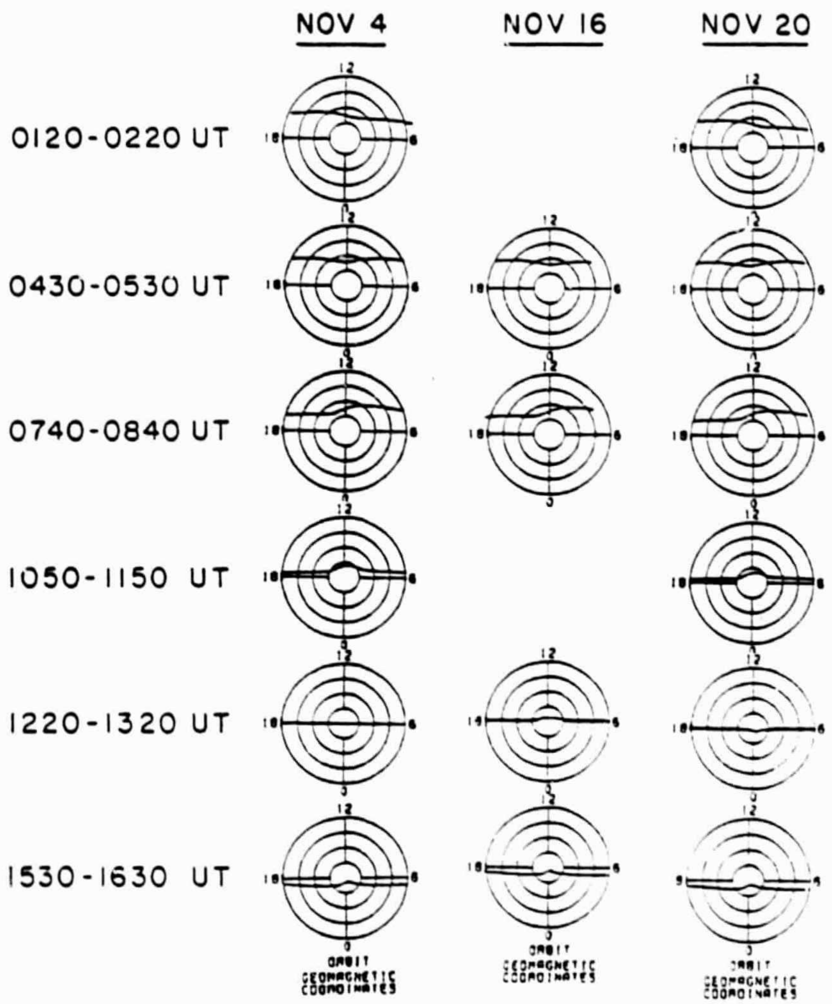
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Figure 5

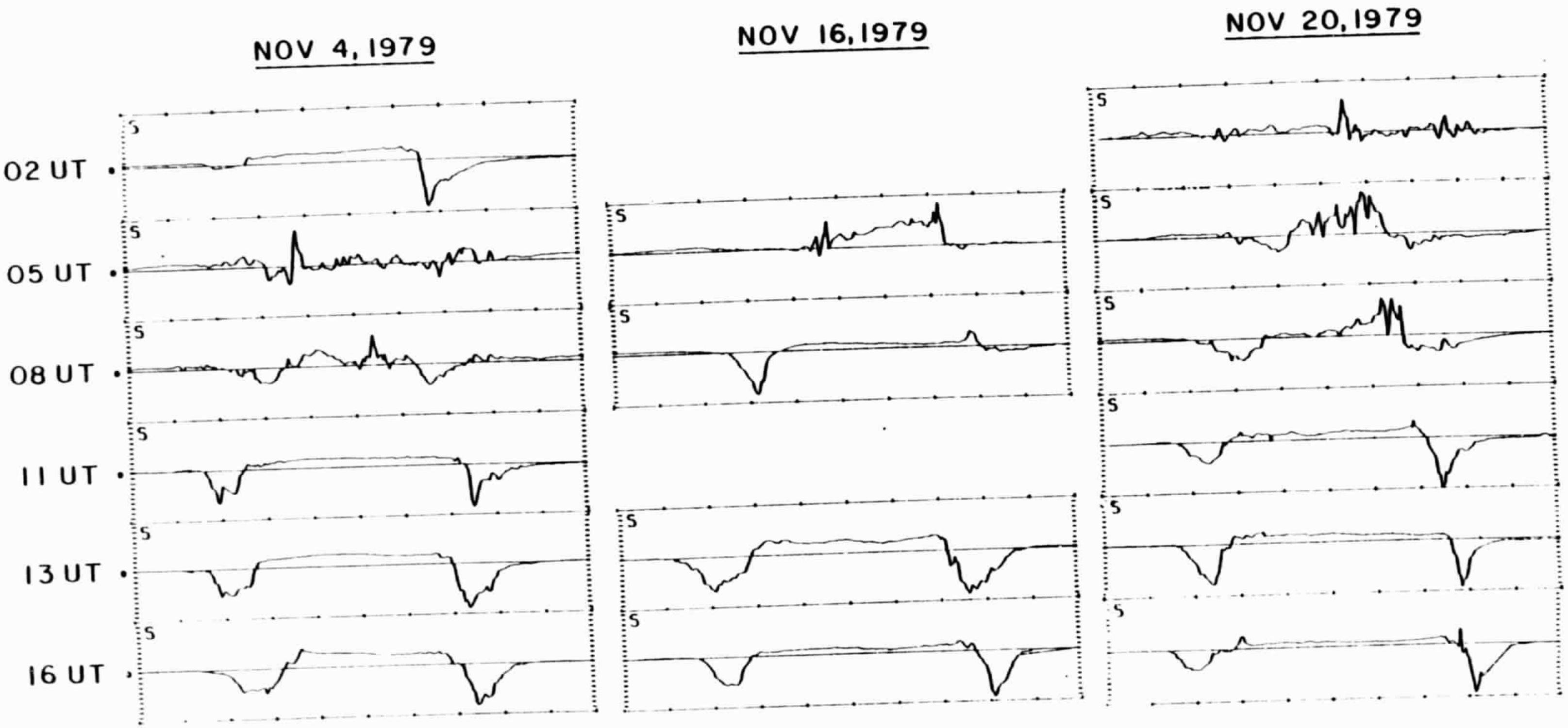
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Figure 6

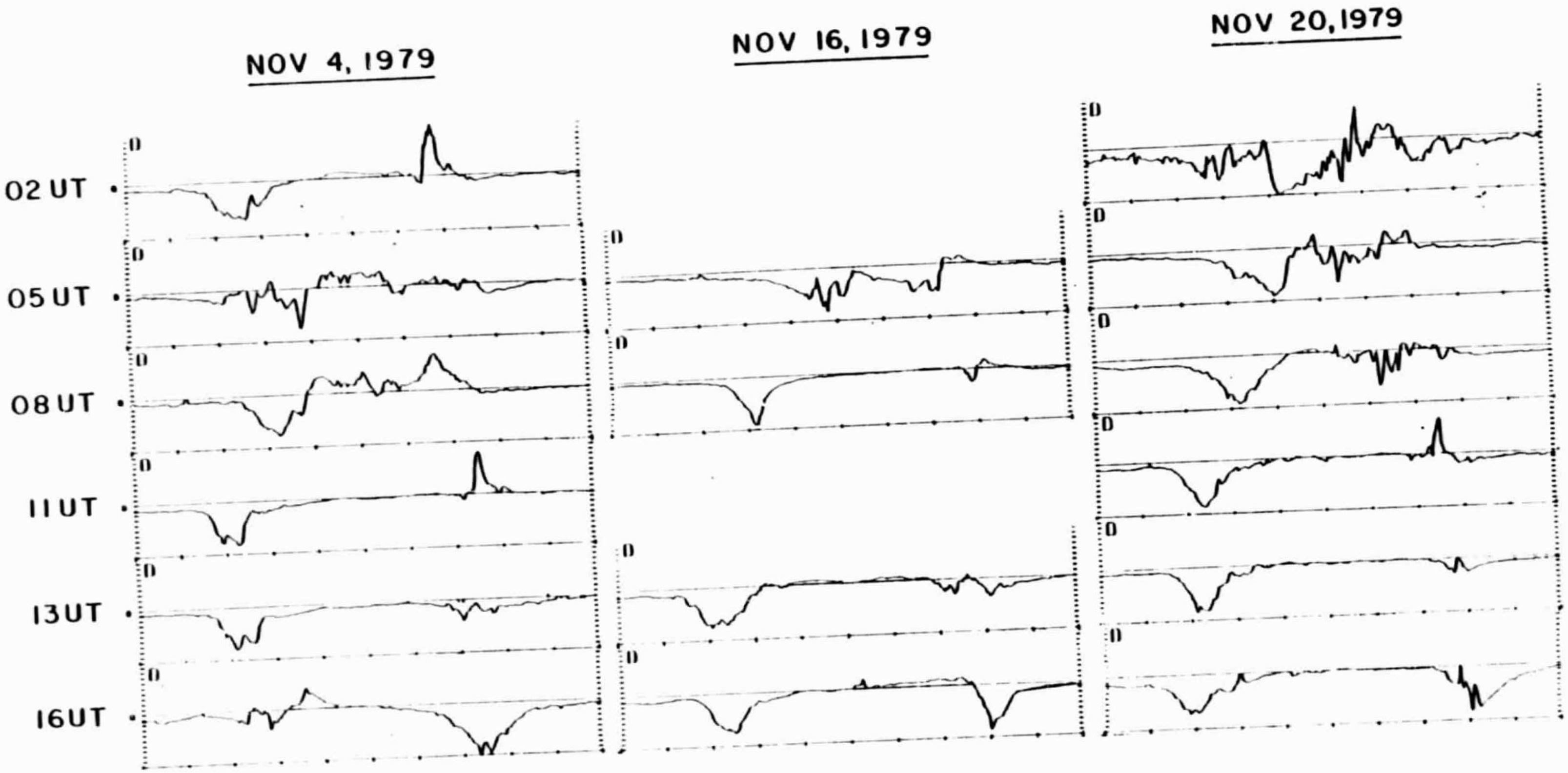
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Figure 7

Magsat observations taken when the satellite passes over the surface location in question. All Magsat passes over the location in question will occur at one or the other of two particular universal times, namely when the earth rotates through the orbital plane of the satellite. Thus each point on the ground has magnetic values associated with it that are taken at only two specific and unique universal times. Since at each particular universal time there is a consistent and unique magnetic perturbation associated with the external currents, the magnetic signature attributed to each surface location will have a consistent component due to the external high latitude currents as well as to any crustal anomaly that might be present. Thus great caution must be exercised when inferring magnetic anomalies at middle and high latitudes. Simply removing temporal variations or picking magnetically quiet days will not remove the consistent and repeatable external current effects discussed here.

B. Field Modeling

It was originally envisioned that this research project to model the magnetic fields of certain distributed currents in space would utilize the techniques developed by J. L. Kisabeth and would extend the capabilities of that method as required. During the early stages of the project that technique was evaluated as to its applicability to the problem at hand with due consideration of the available resources. It was found that, although the technique is a sound one, it nevertheless carried with it a number of constraints which limited its scope and made it less desirable than it first appeared. One severe limitation contained in that modeling technique was the existence of artificial upper and lower latitude cutoffs for the input current system. Currents existing high in the polar cap could not be

conveniently handled by the Kisabeth model. As it was our desire to model the fields due to distributed currents with little or no artificial constraints on their geometrical distribution, this limitation was considered to be undesirable. Correcting this situation would have required considerable modification to the existing software. A second limitation lay in the resolution within which currents could be specified. The Kisabeth grid cell model existing in 1980 could handle currents specified in a grid cell having the dimensions of only 2° of latitude by 15° of longitude. It was considered desirable to work with higher resolution than this since real ionospheric current variations on a smaller spatial scale than 2° by 15° were expected. This limitation was not considered to be insurmountable. It would have been possible to expand the number of grid cells to gain higher resolution, however the price would have entailed an inordinate increase in the required computational resources. Already the existing programs required a large computer and a relatively large computing budget. A computer run costing several hundred dollars would have been necessary each time a set of kernals was needed to be generated. Because of the exploratory nature of the proposed investigation our limited computer budget would have been quickly depleted.

In order to bypass the limitations discussed above we began to consider alternative techniques. We were driven by the desire to develop an efficient but accurate technique that would not seriously restrict the form or magnitude of the input current distribution. Furthermore, any new method developed would have to be capable of operating on a small computer such our PDP 11/45 computer, for which no time-base operating charges are assessed. As various alternatives were reviewed, it became clear that a

relatively straight forward approach utilizing the most basic laws of magnetism and vector mathematics might be best suited to the available resources.

The magnetic field computation technique thus developed is based upon the additive properties of vector fields. In general, the field vector at a point in space is the vector sum of the vector components arising from all of the elemental field sources in the universe. In the present case, the magnetic field at a point is computed by summing the contributions of all of the assumed currents that exist everywhere in space. The assumed current distribution is modeled by decomposing the actual current distribution into an arbitrary number of finite length current elements. The technique itself relies upon the use of an analytical expression for the magnetic field of a straight current carrying filament having an extended and smoothly varying cross-sectional current density. The cross-sectional current density profile looks somewhat like a square wave pulse with rounded corners. The use of such a platykurtic distribution has been found to eliminate discontinuities that exist in a square wave representation and allows for easy calculation of the vector magnetic field at any point in the world space.

The total current distribution to be calculated is represented by an arbitrary number of these finite length current elements. Typically several hundred such current elements are used to represent the horizontal and field-aligned current distribution over the high latitude ionosphere. By a suitable summation of the field at each point due to the contributions from all current elements, the magnetic field may be calculated anywhere, such as on the earth's surface or along a satellite orbit. The resultant

magnetic perturbations for each vector-field component are displayed on a high resolution vector graphics terminal by means of a computer program designed to allow the operator to interactively modify the model parameters. The initial development of this model was restricted to a hypothetical satellite orbit at 90^{o} inclination in the dawn dusk meridian plane and the initial computations included only the sunward component of the perturbation field at various constant altitudes. A sample plot of the output from this initial model is shown in figure 8. The main plot on this figure shows the sunward directed component of the magnetic field calculated at 94 separate observation points as a function of latitude along a hypothetical orbit at a constant altitude of 500 km. The input current system is a "classical" large-scale Birkeland sheet current model with downward directed currents in the high latitude postmidnight and the low latitude pre-midnight portions and upward directed currents in the high latitude pre-midnight and low latitude postmidnight sectors. This current system is represented computationally in this example by 324 linear current elements as described above. The field-aligned currents are closed by N-S currents in the ionosphere at 110 km altitude. No E-W ionospheric currents have been included. The center of the current sheets are located in the figure by the vertical lines at 70.5° and 77.5° latitude. The latitudinal distribution of current intensity is plotted along the top of the main panel. The clock dial in the lower right-hand quadrant depicts the satellite orbit.

Following this initial development the capabilities of the model were extended considerably to allow the computation of all three vector components of the magnetic field arising from an assumed current system. The

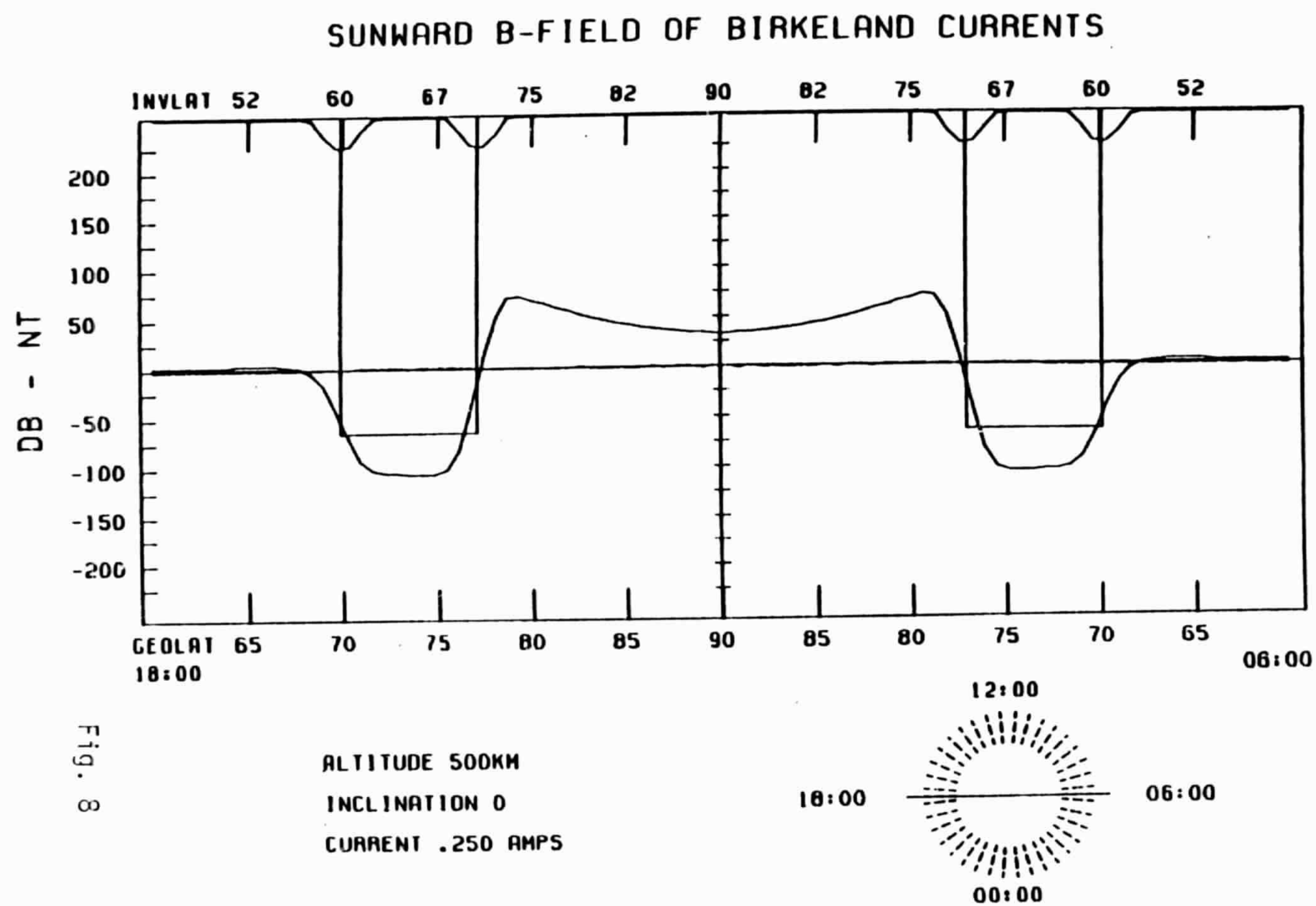


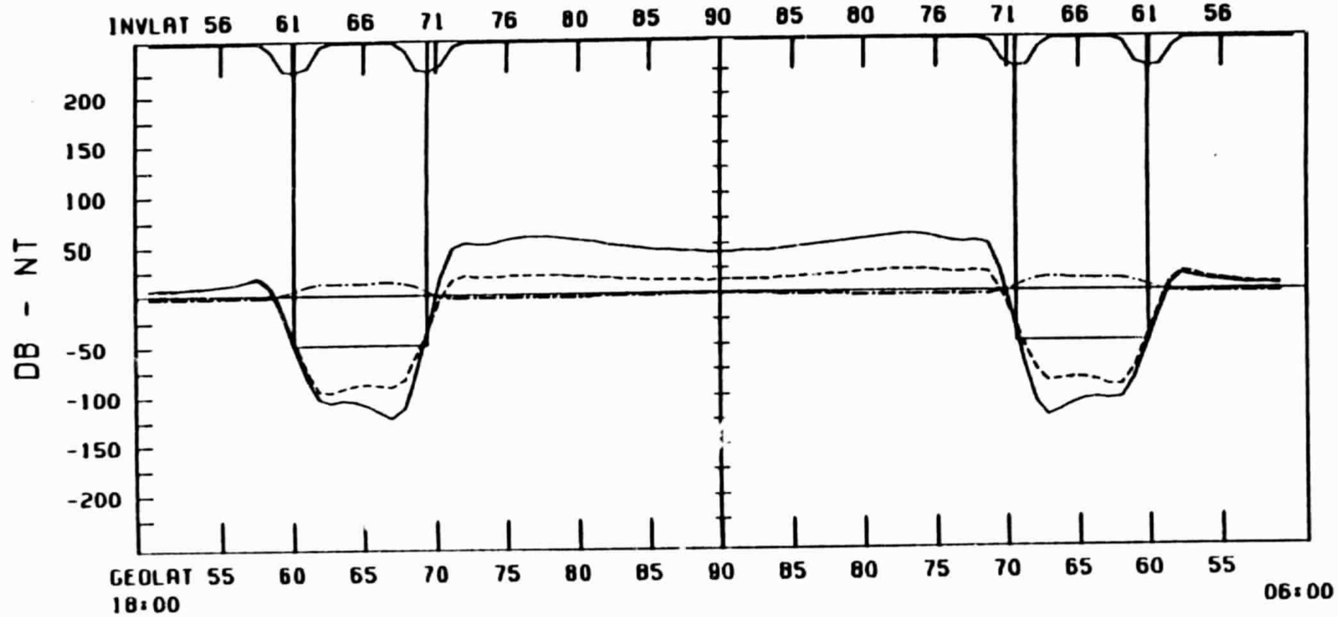
Fig. 8

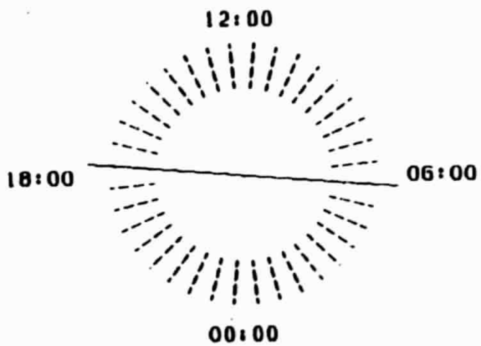
CL1 12.5 CL2 19.5 CL3 7.0 FR .000 IU 10.0 ID 20.0 DST .250

restriction on possible satellite orbits was also almost entirely eliminated allowing the magnetic field components to be computed for virtually any satellite orbit over a range of inclinations and altitudes and having an arbitrary angle between the orbital plane and the earth-sun line. Figures 9 through 12 show sample plots of the model magnetic field output for a satellite at 500 km altitude with various orbital inclination angles. The main plots on these figures show three orthogonal components of the magnetic field each calculated at 94 separate observation points as a function of latitude. The solid curve is the sunward component, the dot-dash curve is the dawn-dusk component and the dashed curve the vertical component. The input current system is a "classical" large-scale Birkeland sheet current model with downward directed currents in the high latitude postmidnight and the low latitude pre-midnight portions and upward directed currents in the high latitude pre-midnight and low latitude postmidnight sectors. This current system is represented computationally in this example by 324 linear current elements as described above. The field-aligned currents are closed by N-S currents in the ionosphere at 110 km altitude. No E-W ionospheric currents have been included. The centers of the current sheets are located in the figures by the vertical lines at 61° and 70° invariant latitude. The latitudinal distribution of current intensity is plotted along the top of the main panel. The clock dial in the lower right-hand quadrant again depicts the satellite orbit.

Two additional extensions of the magnetic field modeling software were then made that significantly extended the ability of the model to handle realistic current systems and display the results more realistically. The capability for ionospheric current closure in the east-west direction was

SUNWARD B-FIELD OF BIRKELAND CURRENTS





ALTITUDE 500KM

INCLINATION 0

CURRENT .400 AMPS

CL1 20.0 CL2 29.0 CL3 10.0 FR .000 IU 10.0 ID 20.0 DST .400

Figure 9

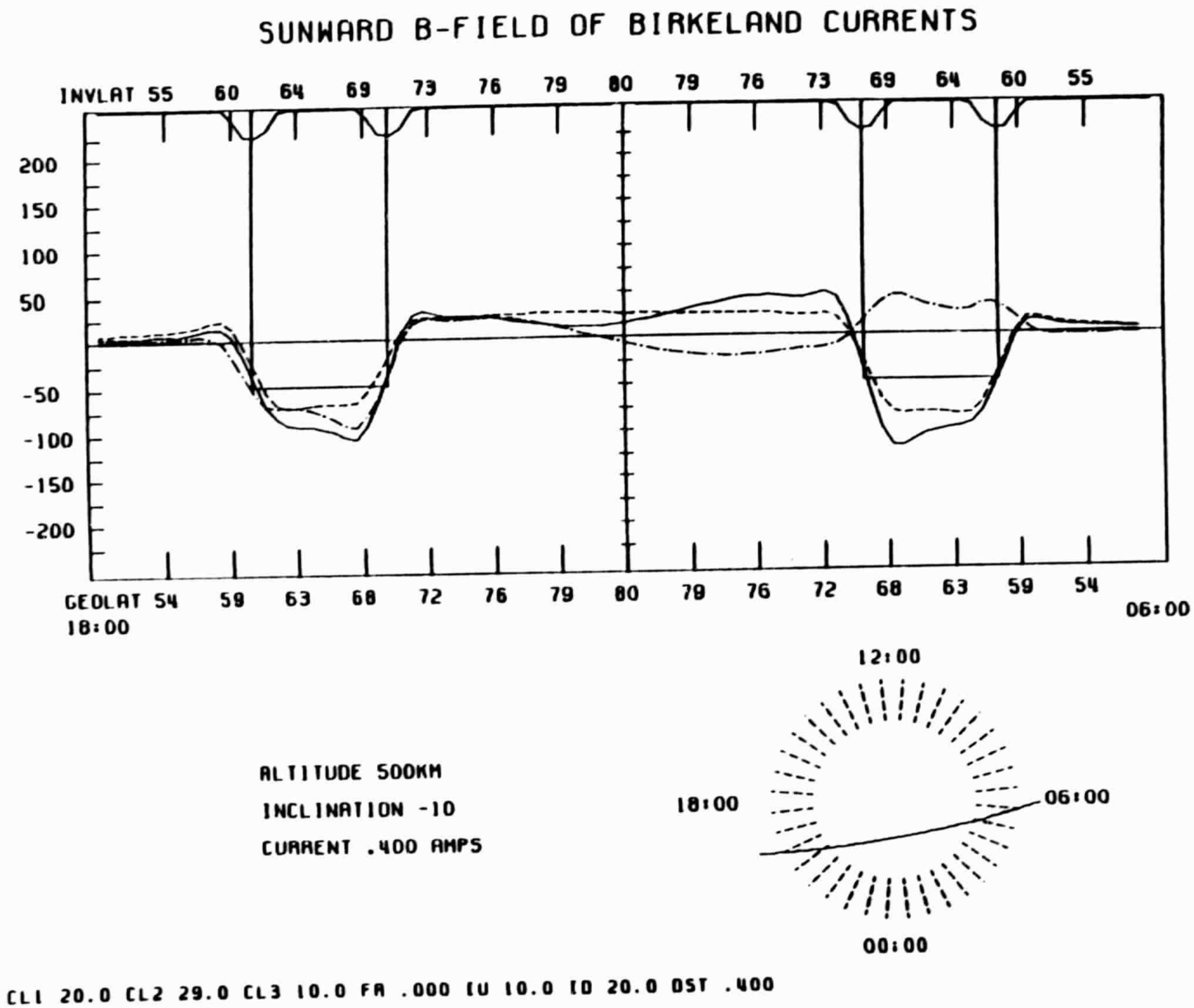

SUNWARD B-FIELD OF BIRKELAND CURRENTS
INVLAT 55 60 64 69 73 76 79 80 79 76 73 69 64 60 55
200
150
100
50
-50
-100
-150
-200
DB - NT
GEOLAT 54 59 63 68 72 76 79 80 79 76 72 68 63 59 54
18:00
06:00
ALTITUDE 500KM
INCLINATION -10
CURRENT .400 AMPS
12:00
18:00
06:00
00:00
CL1 20.0 CL2 29.0 CL3 10.0 FA .000 IU 10.0 ID 20.0 DST .400

Figure 10

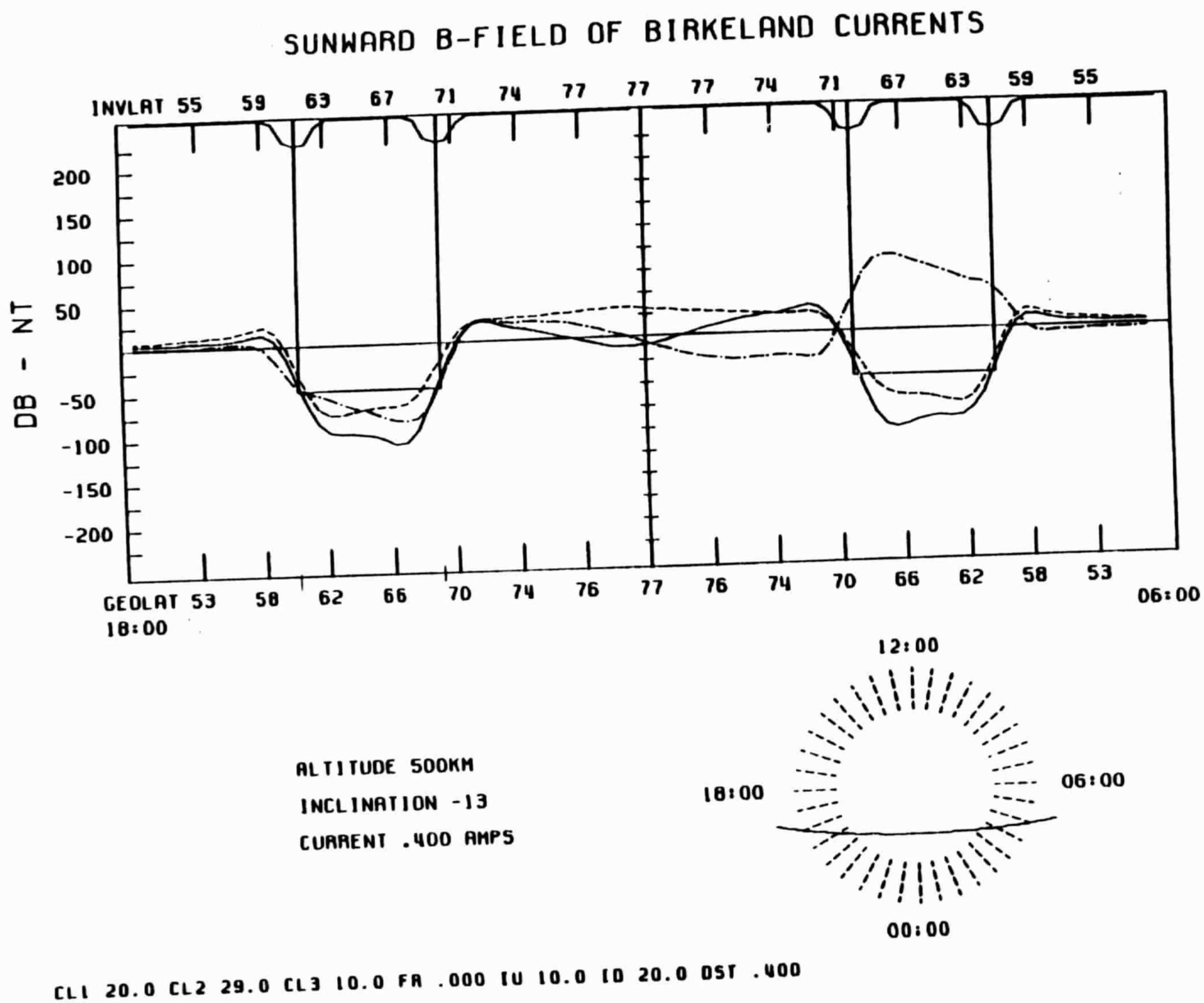
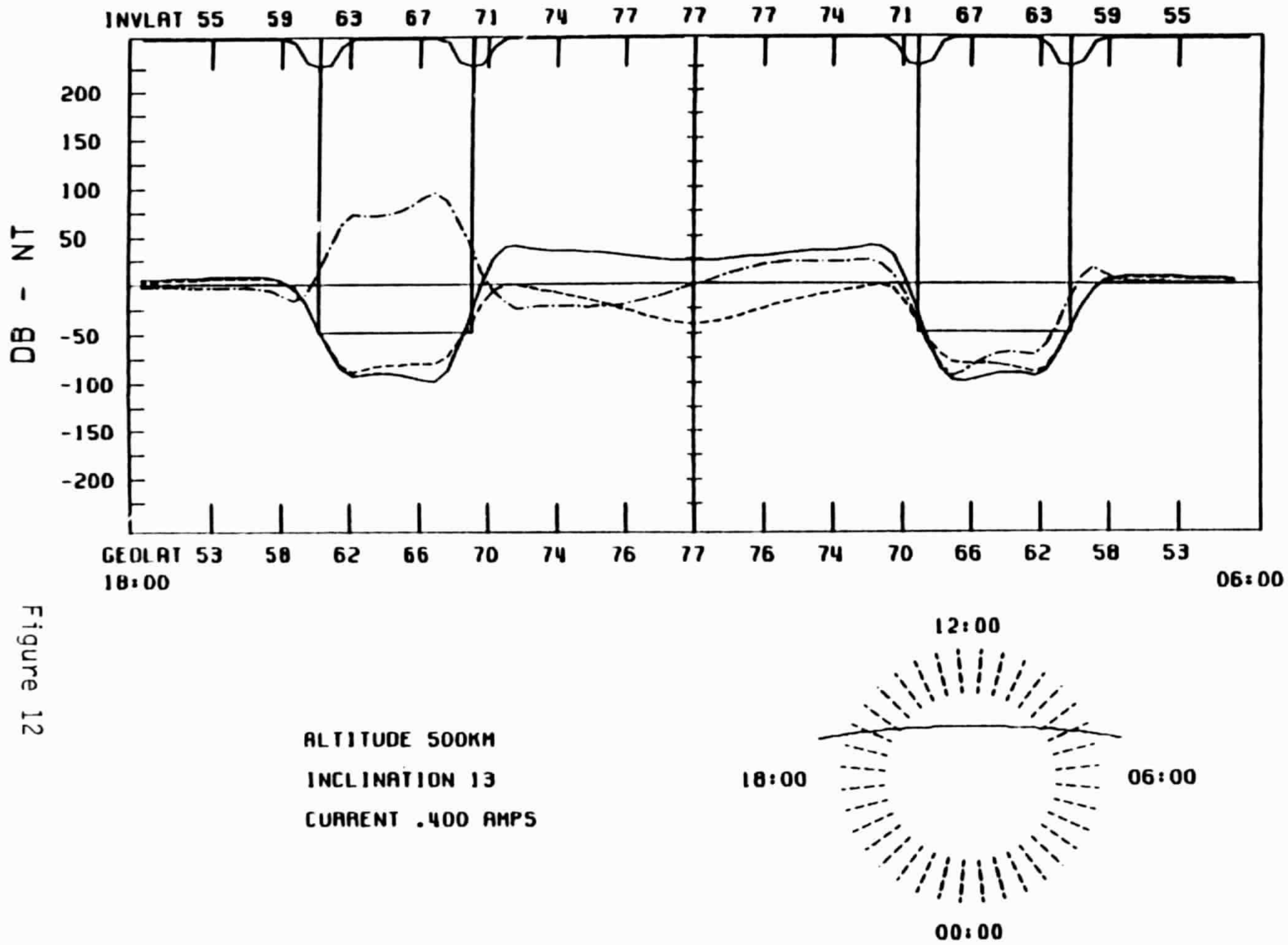

SUNWARD B-FIELD OF BIRKELAND CURRENTS
INVLAT 55 59 63 67 71 74 77 77 77 74 71 67 63 59 55
DB - NT
200
150
100
50
-50
-100
-150
-200
GEOLAT 53 58 62 66 70 74 76 77 76 74 70 66 62 58 53
18:00
06:00
ALTITUDE 500KM
INCLINATION -13
CURRENT .400 AMPS
12:00
18:00
06:00
00:00
CL1 20.0 CL2 29.0 CL3 10.0 FA .000 IU 10.0 ID 20.0 DST .400

Figure 11

SUNWARD B-FIELD OF BIRKELAND CURRENTS



CL1 20.0 CL2 29.0 CL3 10.0 FR .000 IU 10.0 ID 20.0 DST .400

Figure 12

built into the model. Furthermore, the resulting magnetic field perturbations could additionally be computed and plotted in an N,E, V coordinate system.

Figure 13 is a schematic representation in the magnetic local time-magnetic latitude coordinate system of the linear current elements used to model, to zeroth order, the naturally occurring field-aligned currents above the high latitude ionosphere. Each circle with its appropriate cross-hatching represents the location, current intensity, and current flow direction for a linear current element. The superposition of all these current elements approximates a "classical" large-scale Birkeland sheet current model with downward directed currents in the high latitude postmidnight and the low latitude pre-midnight portions and upward directed currents in the high latitude pre-midnight and low latitude post-midnight sectors. For this particular instance low-level distributed inward field-aligned currents exist between 0800 and 1600 hours on the dayside and similar outward directed currents appear on the nightside. These distributed currents are necessary to maintain continuity of the horizontal ionospheric closure currents shown in Figure 14. In this figure the arrows represent the direction and relative magnitude of the Hall and Pedersen ionospheric closure currents. For the current system illustrated here the majority of the Birkeland current closure occurs in the N-S direction with the eastward and westward closure currents becoming proportionally stronger near the dusk and dawn sectors respectively and decreasing to zero near noon and midnight.

Figures 15 and 16 depict the magnetic perturbations that would be observed by magnetometers on a satellite along two hypothetical orbits that pass through the modeled current system at an altitude of 450 km. In each

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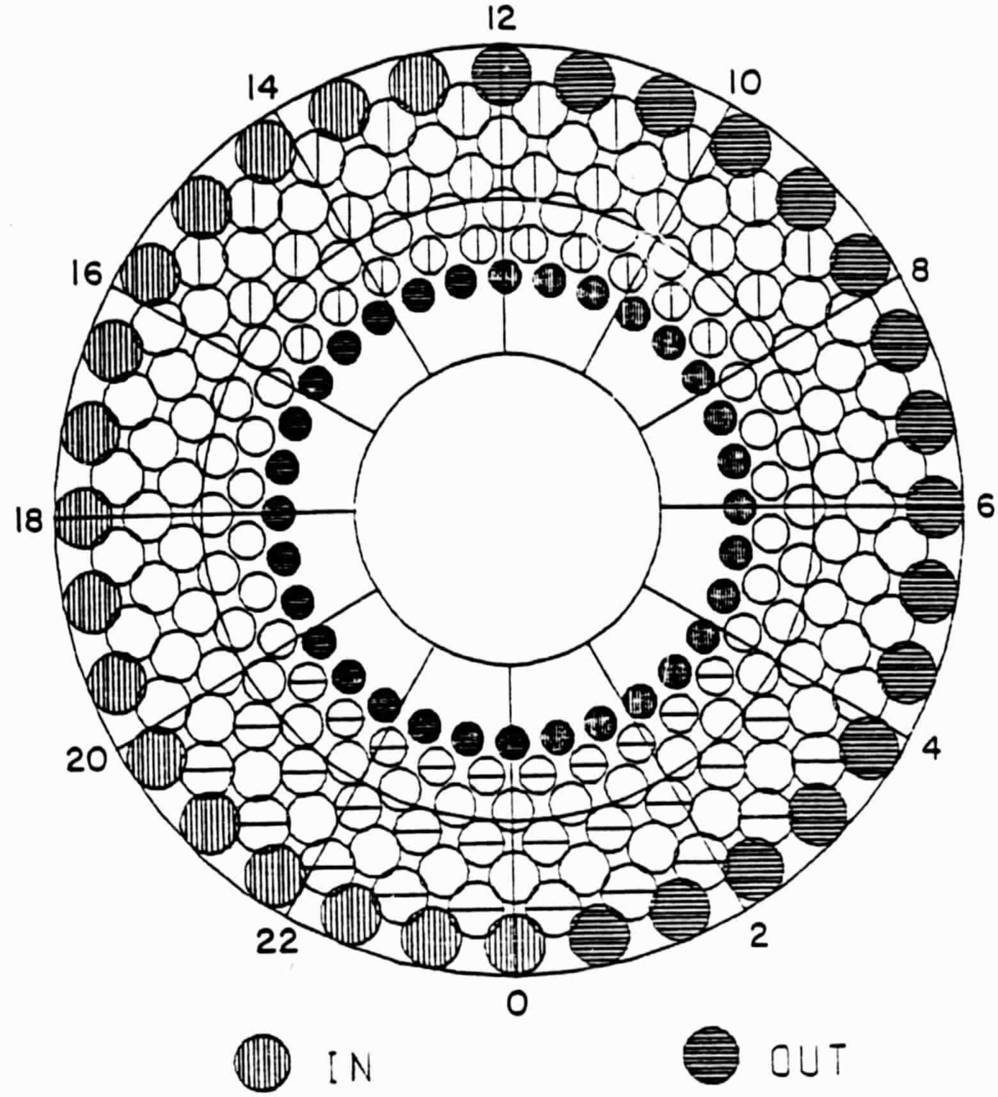
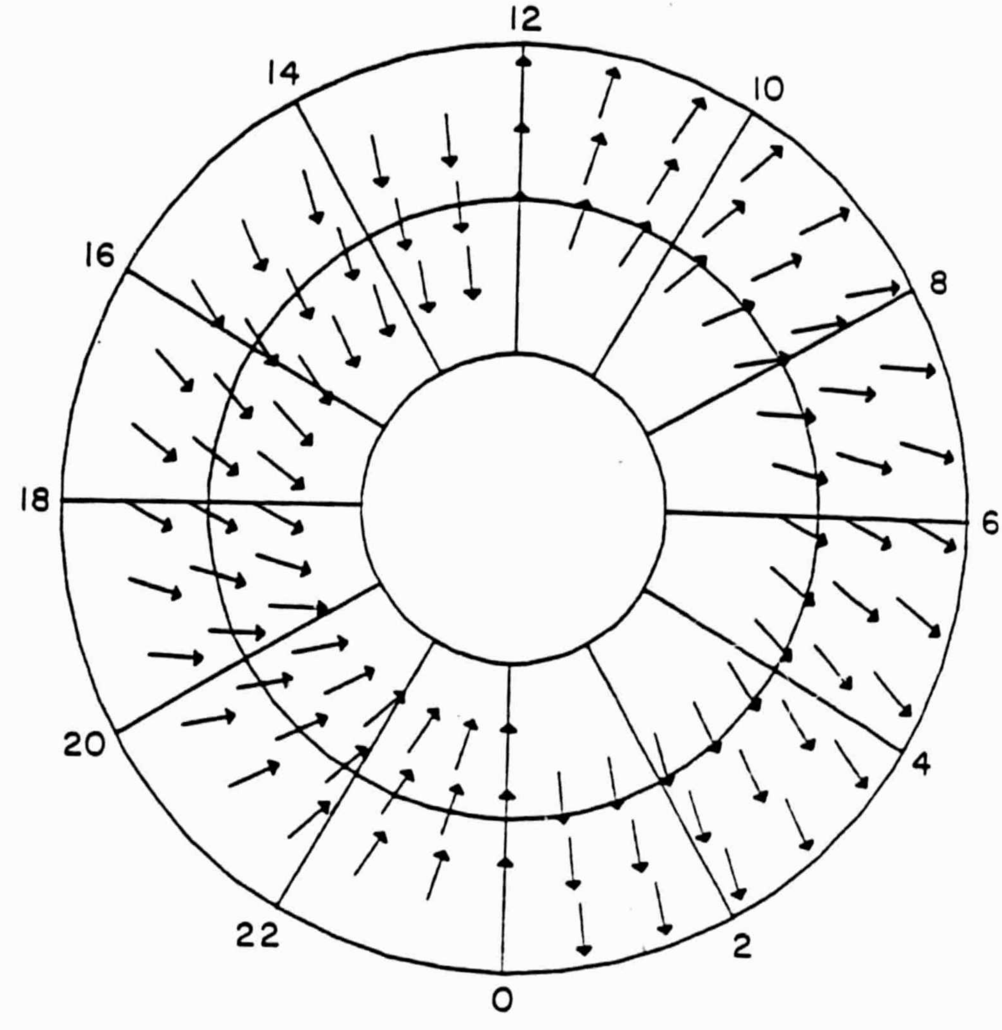


DISTRIBUTION OF FIELD ALIGNED CURRENTS

Figure 13



DISTRIBUTION OF IONOSPHERIC CURRENTS

Figure 14

B-FIELD OF BIRKELAND CURRENT SYSTEM

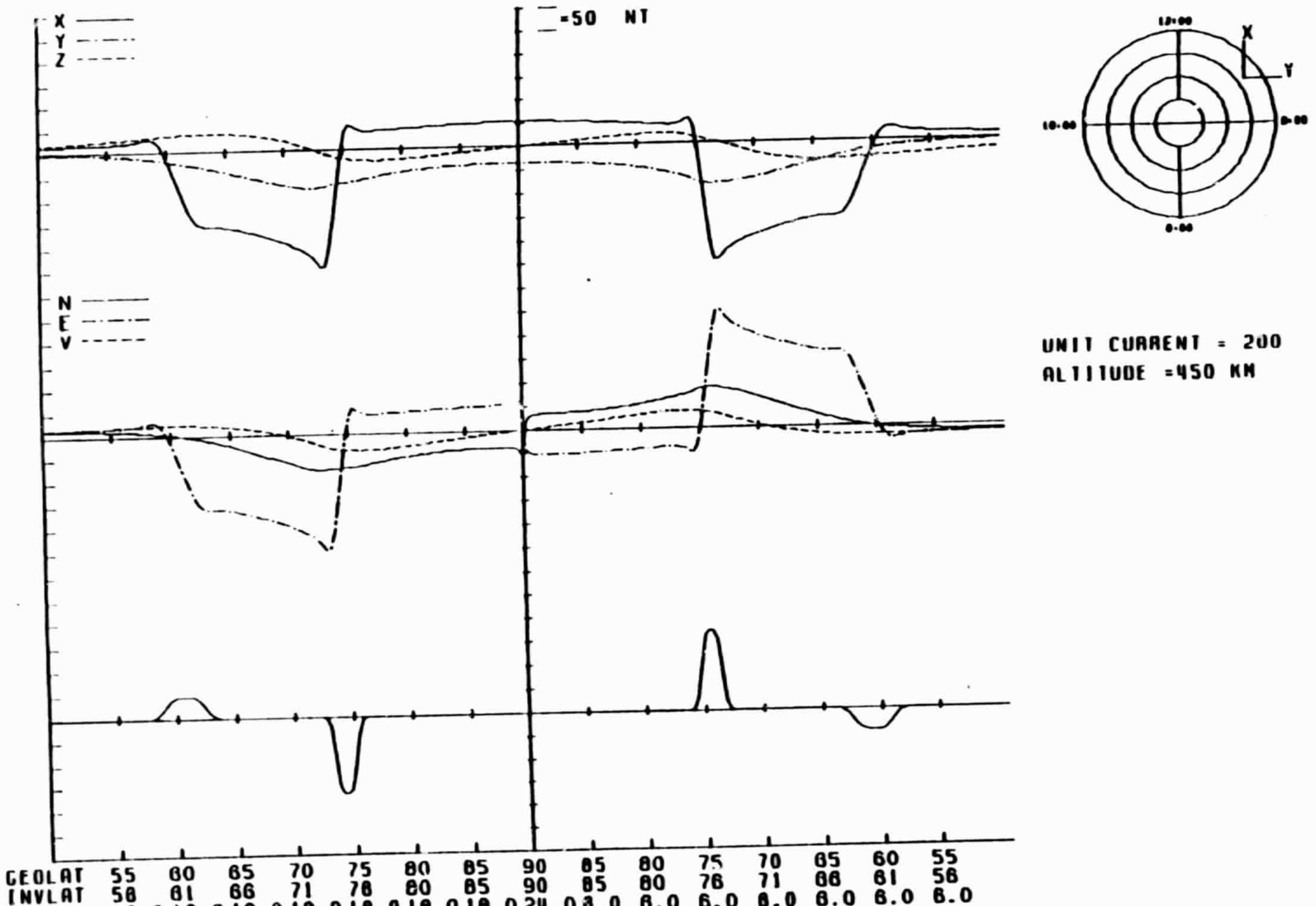


Figure 15

B-FIELD OF BIRKELAND CURRENT SYSTEM

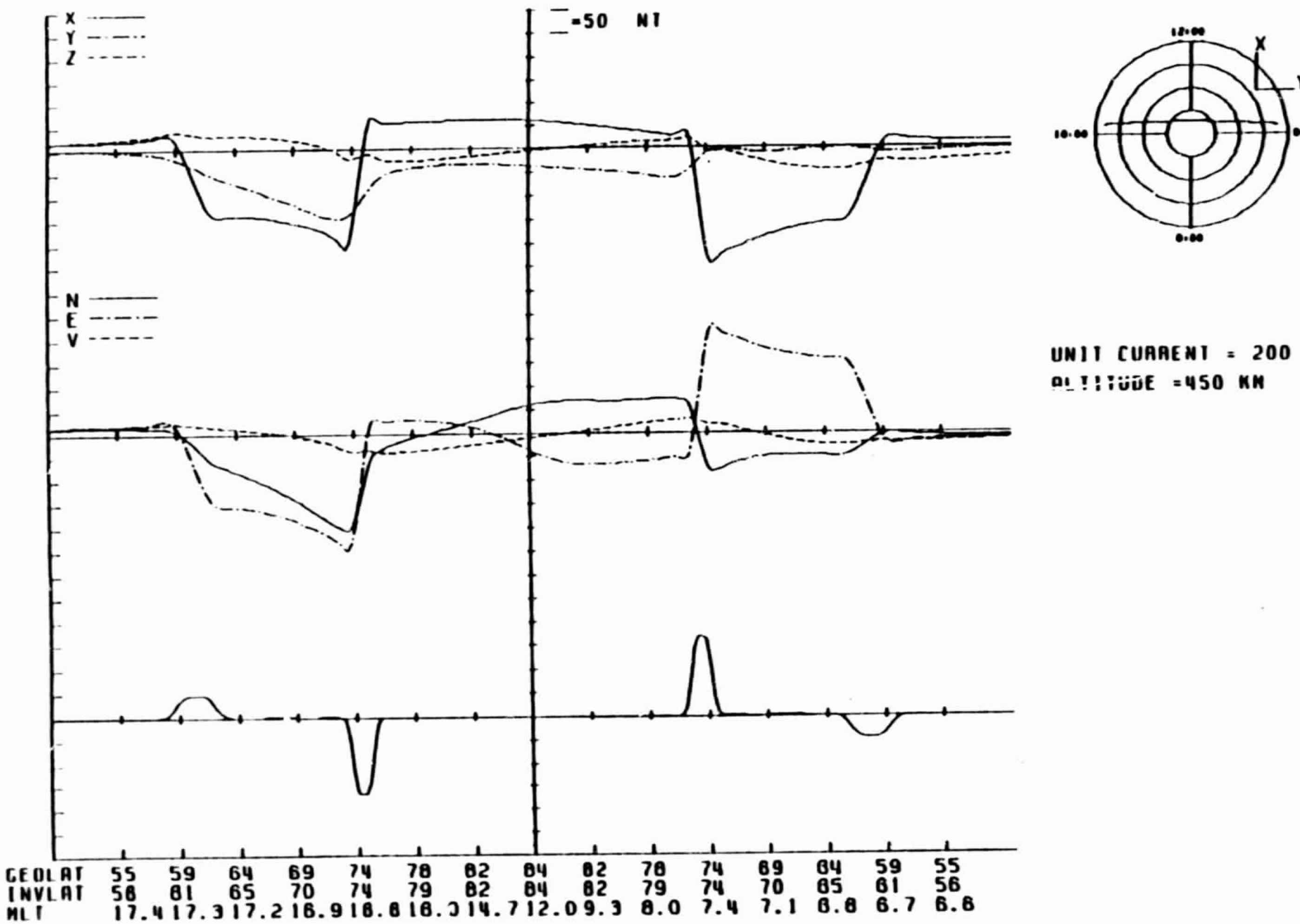


Figure 16

36

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figure the upper panel shows the latitudinal profile of the three vector components of B in an X,Y,Z coordinate system while the center panel depicts the field components in the more conventional N,E,V coordinate system. Shown in the bottom panel of Figures 15 and 16 are the field-aligned current densities encountered at each point along the satellite orbit. The clock dial in the upper right quadrant depicts the satellite orbit in a Magnetic Local-Time and Invariant Latitude coordinate system. In Figure 15 the satellite has an orbital inclination of 90^{o} and its orbital plane is contained in the dawn-dusk meridian. As expected the major perturbation in the magnetic field appears in the east-west component and has its greatest gradient co-located with the local field-aligned current. In Figure 16 a slightly different orbit has been chosen with an orbital inclination of 96^{o}. Now the satellite passes slightly to the dayside of the dawn-dusk meridian. Comparison with Figure 15 reveals that the east-west magnetic component is virtually unchanged whereas a substantial N-S component has now developed in the magnetic field. This kind of comparison illustrates the strong effect that relatively small displacements in the location of the measuring point can have upon the vector magnetic field.

At this stage the model had reached a level of development whereby extensive testing of its predictive capabilities could begin. Pursuant to that end, we took the initial steps to conduct comparative modeling of an agreed-upon input ionospheric and field-aligned current system in cooperation with the National Research Council of Canada group. A second test of one portion of our new modeling package was carried out using a horizontal ionospheric current system published by Akasofu et al (1981). These researchers have deduced a model of the total ionospheric current distribu-

tion based upon five minute averages of the magnetic field measured on the ground with the Alaska Meridian Chain of Magnetometers. Using a likeness of their ionospheric current distribution from Figure 4 of the referenced paper, we have calculated the three-dimensional field-aligned current distribution around the polar ionosphere that would be required to maintain continuity of the total current system. Our results are shown in Figure 17. This figure is a color-coded representation of the direction and magnitude of the resulting field-aligned current densities over the polar region. The color hues of the red-orange-yellow portion of spectrum represent varying intensities of downward directed currents and those of green and blue represent various intensities of upward directed currents as shown in the bar scales in the lower right hand corner. The gross features of this plot closely resemble those deduced by Akasofu et al. and shown in their Figure 5. This pattern is also generally consistent with the overall empirical distribution of Region 1 and Region 2 field-aligned currents deduced from satellite data. Our model has also been used to produce the magnetic field perturbations that would be observed from a satellite passing through this current system, as well as those that would be observed on the ground below. Those latter distributions should compare with the input magnetic field measurements used by Akasofu.

A further test of our modeling capability is, at the time of this writing, being undertaken. It serves as an example of our ability to model complex input current distributions. This test utilizes as input to the model a complex ionospheric current distribution deduced by Y. Kamide of Kyoto Sangyo University in Kyoto, Japan from an extensive set of ground-based magnetic field observations. The ionospheric current distribution

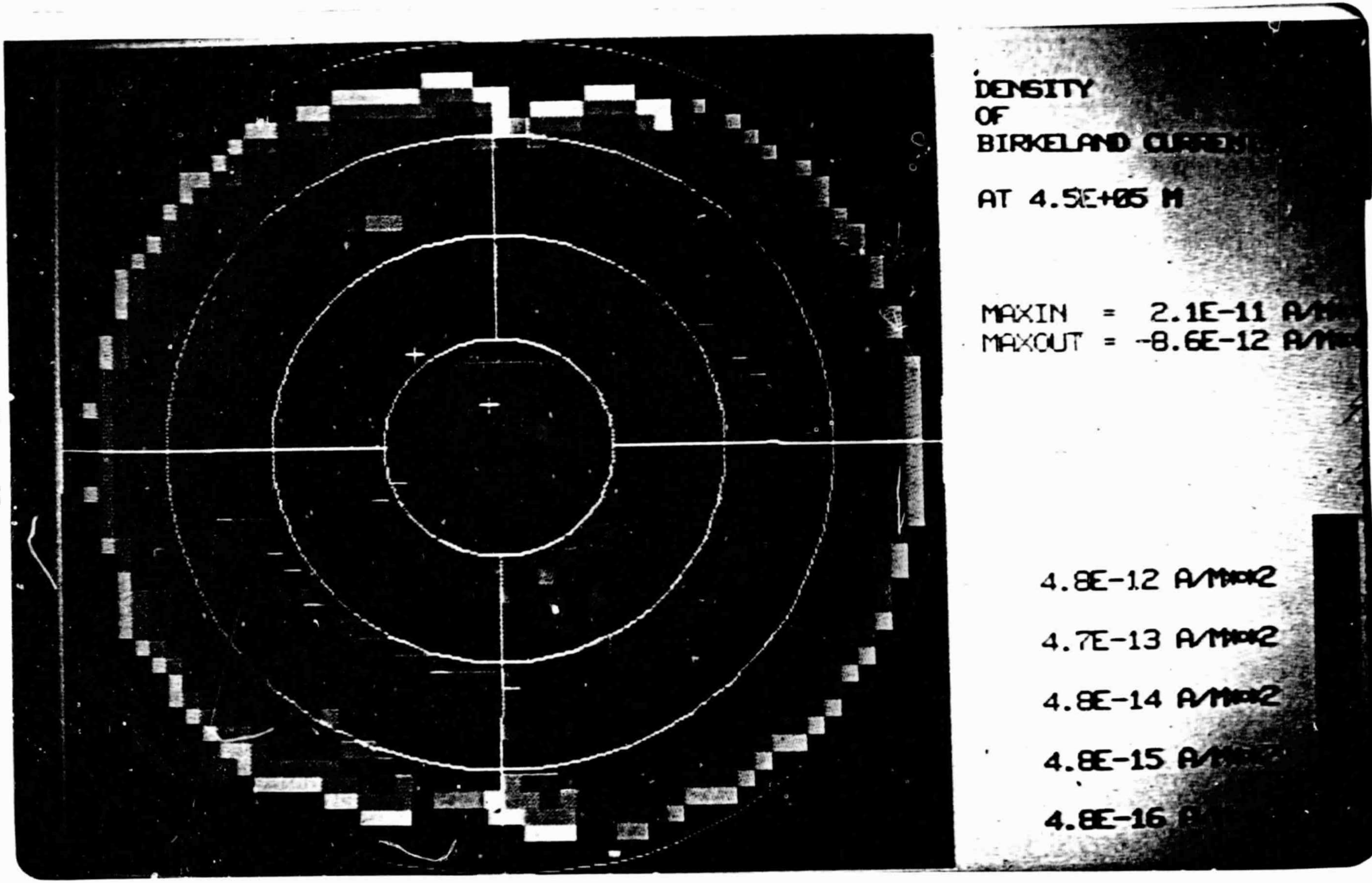

Figure 17

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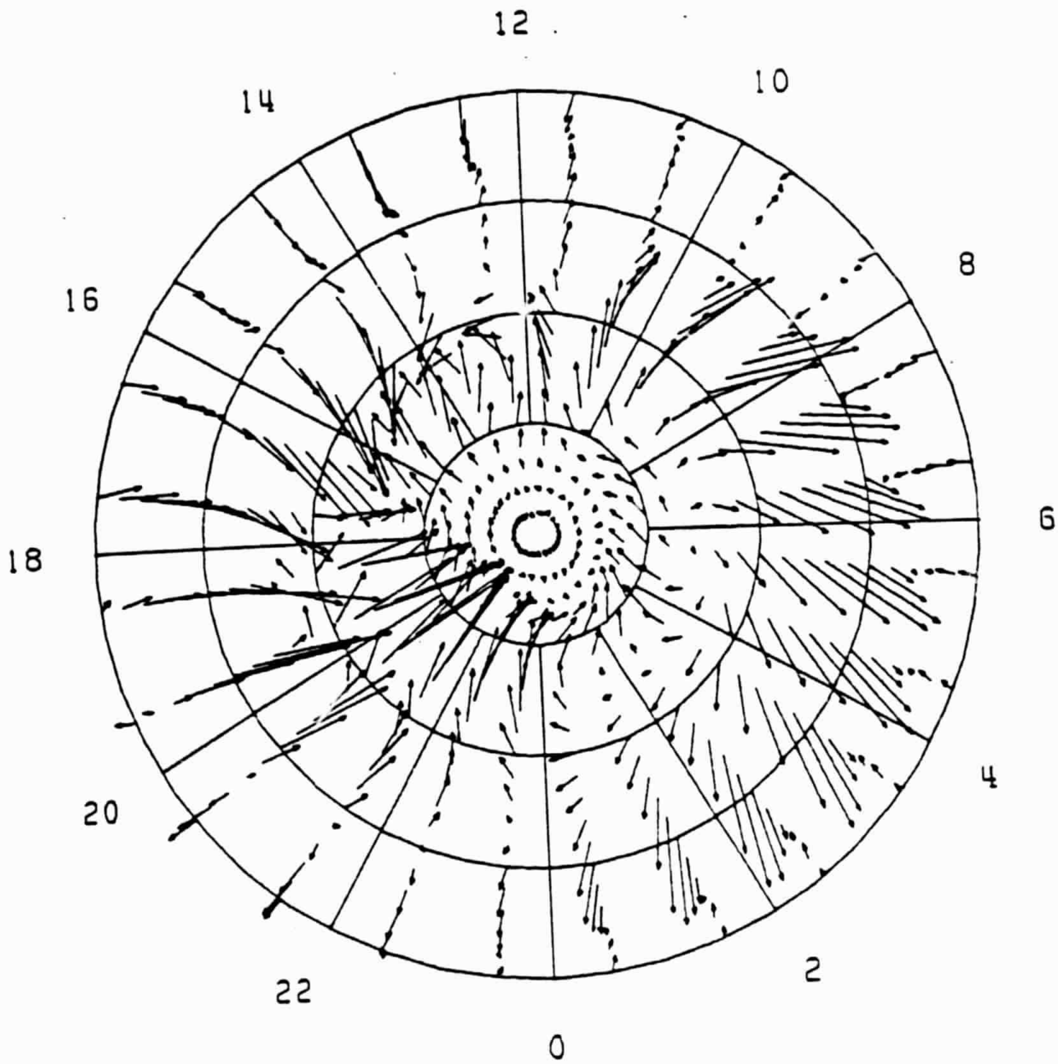
COLOR PHOTOGRAPH

used as input to the model is shown in Figure 18. This figure illustrates the degree of complexity with which our model is capable of operating. With these highly spatial varying horizontal currents and the requirement that the currents be continuous, the field-aligned current distribution required for closure is shown in Figure 19. Combining these ionospheric and field-aligned currents together we model the magnetic perturbations that would be observed at a satellite crossing over the current system as shown in Figure 20. The satellite orbit is shown in the polar dial at the right side of the figure.

One further capability of our modeling procedure is illustrated in Figure 21. Owing to the high computational efficiency and the computational organization of the modeling technique we are not limited to calculating the magnetic perturbations at just a few points or just along a particular satellite orbit. The model easily calculates the vector component perturbations everywhere. This figure shows in a three-dimensional perspective drawing the relative amplitude of one component of the magnetic perturbations at equally spaced grid points everywhere on the surface of a spherical cap at 500 km altitude over the north polar regions down to 50° latitude.

C. Comparisons of Model with Magsat Perturbation Signatures

Our modeling capability now allows us to make direct comparisons between model predictions and actual Magsat perturbations by additional software that allows us to calculate along an an actual Magsat orbit the magnetic perturbations that would be seen at the satellite for an assumed current distribution. This gives us the capability for direct comparison between measured and predicted perturbation fields. By successive iteration

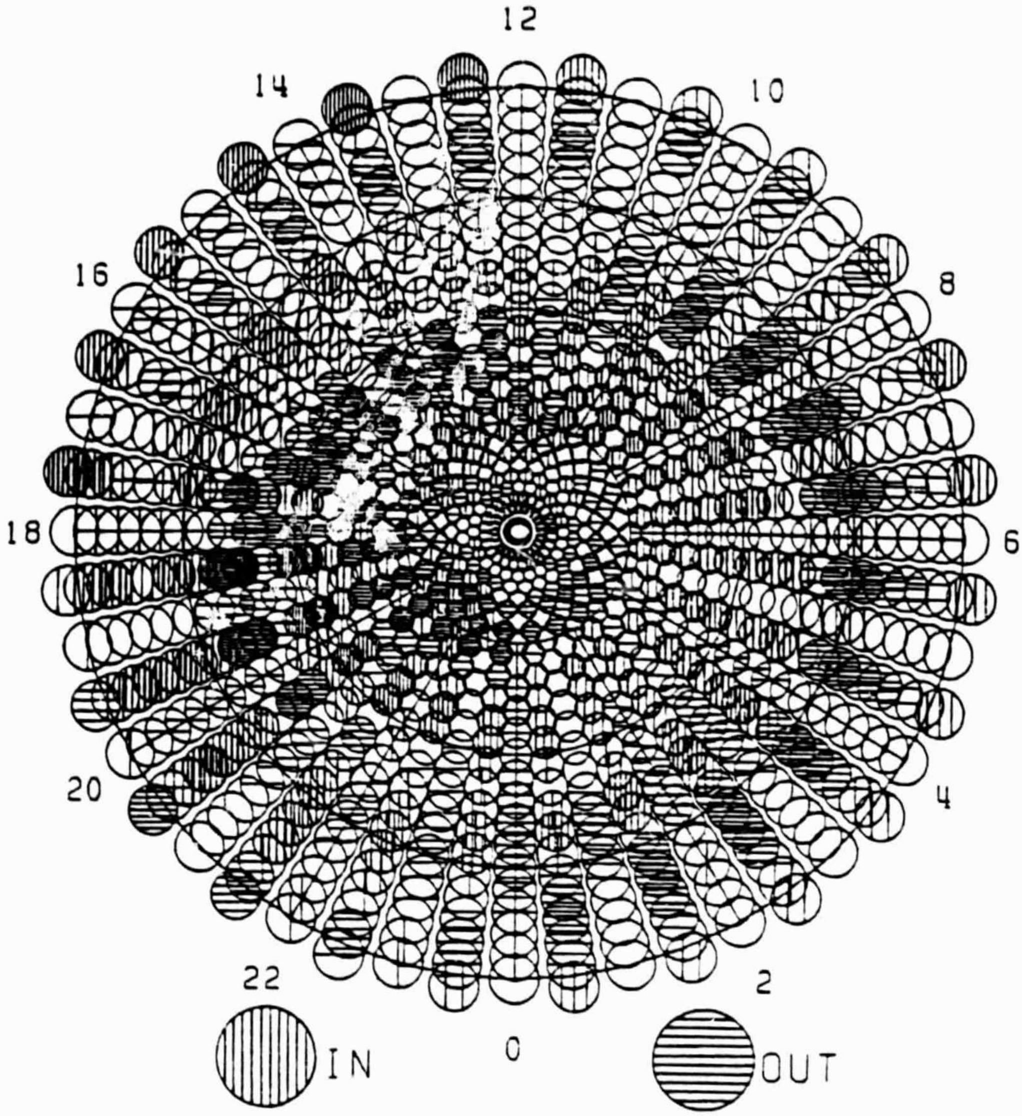


DISTRIBUTION OF IONOSPHERIC CURRENTS

| = 50000.01 AMP

143.1.41.20.24.

Figure 18



DISTRIBUTION OF FIELD ALIGNED CURRENTS

CURRENT IS 5000.00 AMP/LINE

143.1.41.20.24.

Figure 19

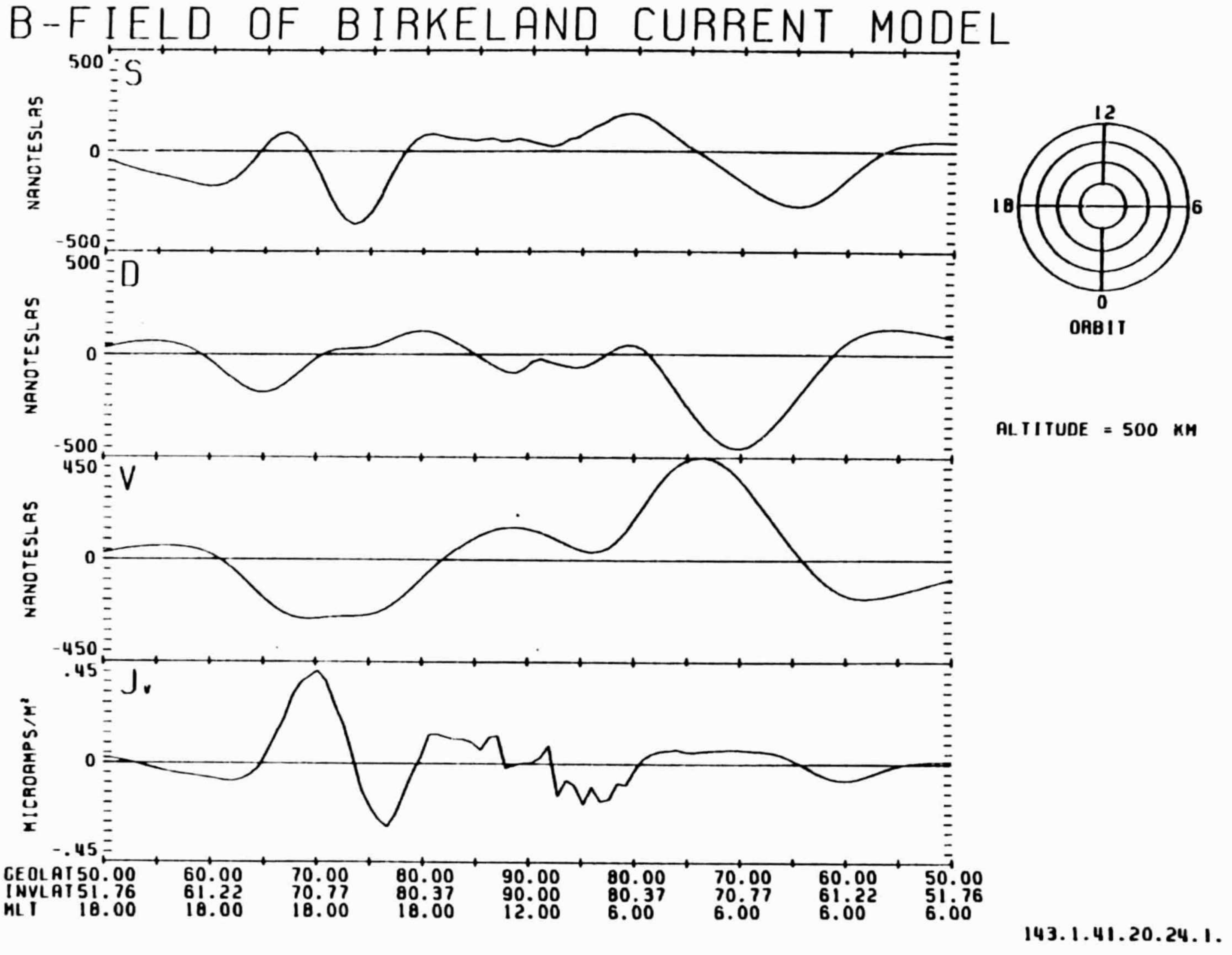
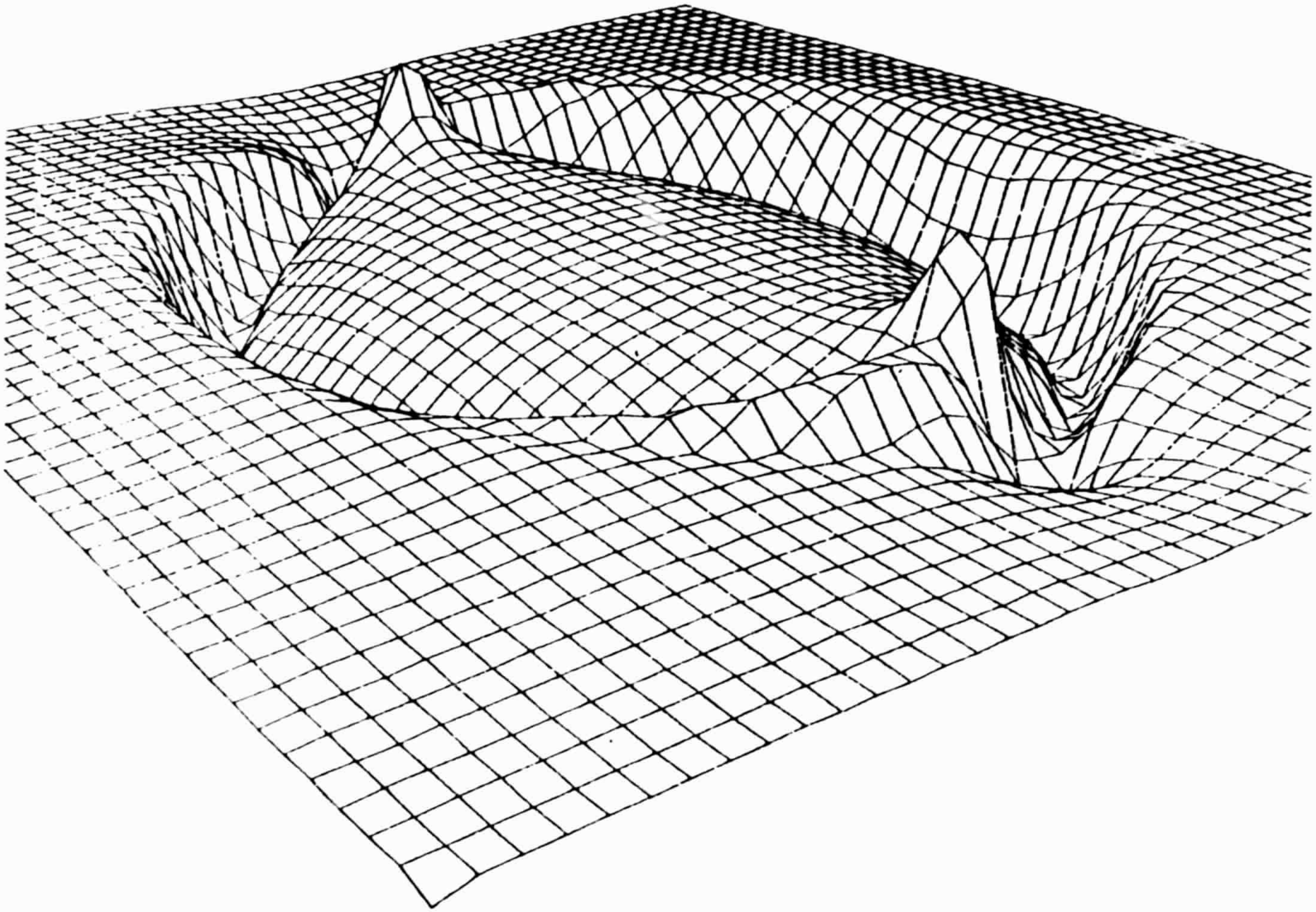

B-FIELD OF BIRKELAND CURRENT MODEL
S
D
V
J_v
500
0
-500
450
-450
.45
-.45
NANOTESLAS
MICROAMPS/M²
GEOLAT 50.00 60.00 70.00 80.00 90.00 80.00 70.00 60.00 50.00
INVLAT 51.76 61.22 70.77 80.37 90.00 80.37 70.77 61.22 51.76
MLT 18.00 18.00 18.00 18.00 12.00 6.00 6.00 6.00 6.00
12
18
6
0
ORBIT
ALTITUDE = 500 KM
143.1.41.20.24.1.

Figure 20



MAXVEC = 6.7E-03NT MINVEC = -1.8E-02NT VECTOR = 2 DIS-CODE = 31. ALTITUDE = 5.0E+05M

Figure 21

of the input current system the current distribution that yields the best fit between the measured and predicted magnetic perturbations can be determined.

An illustration of the effect of large-scale ionospheric and field-aligned (Birkeland) Currents on the Magsat data is shown in Figure 22. The left side of the figure represents model magnetic perturbations calculated from a relatively simple distribution of north-south and east-west ionospheric currents that are fed by classical Region 1 and Region 2 Birkeland currents. The right hand side shows the actual data from Magsat as it passed over the northern polar regions between 10:45 and 11:06 UT on December 4, 1979. The large scale features in all three compoents (North, East, and Vertical) measured at Magsat are reproduced in the model calculations. Note that the relative current strengths have not been optimized in the model so that the scales cannot be directly compared.

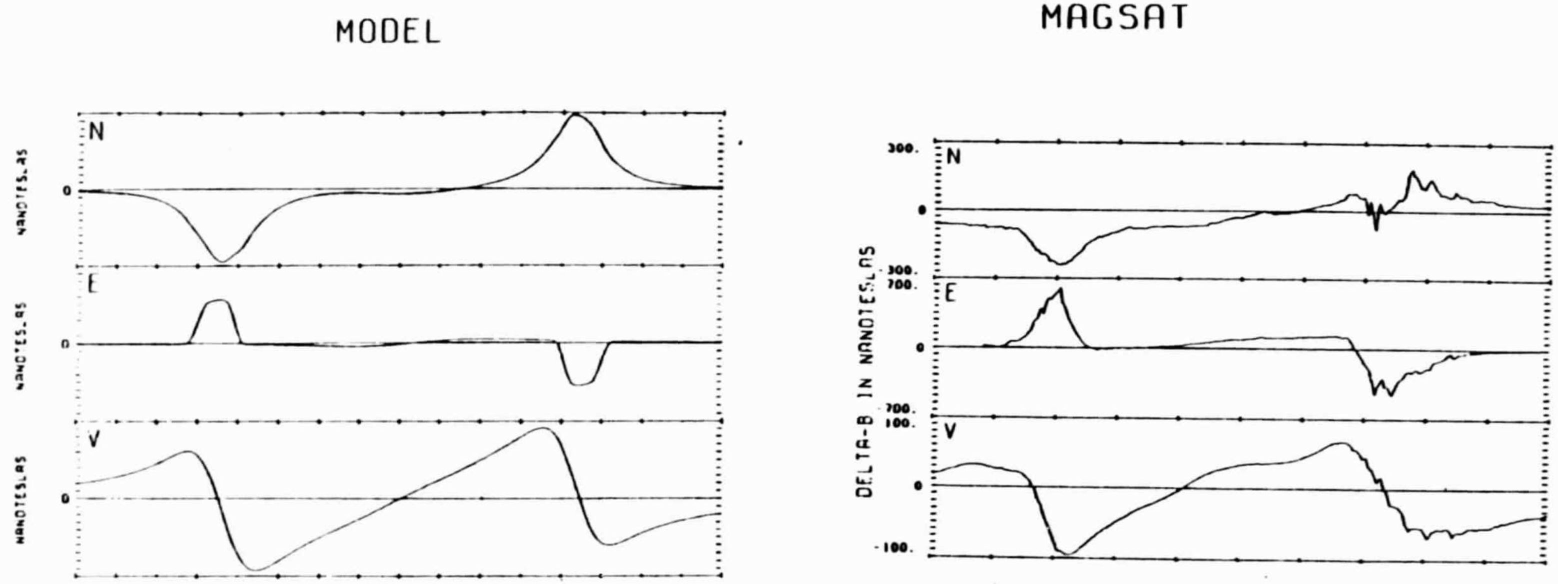

MODEL
MAGSAT
N
E
V
NANOTESLAS
0
300.
700.
100.
-100.
DELTA-B IN NANOTESLAS

Figure 22

IV. SOFTWARE DESCRIPTIONS

A. MAGSAT Chronicle Tape Manipulation Programs

Software described in this section was developed for or modified for use in reducing the Magsat data at the University of Texas at Dallas and graphically displaying the reduced data for further analysis.

1. Tape Reading Programs

MSMDI - Magsat Monitor to Disk

Intended by the original author Ron Cook as a monitor to enable several user selected modes of operation within the data analysis subroutines, and now serves only to tell the user the present date and time and then to call MSDI. This routine was written by Ron Cook and modified by Dale Greer, both of UT-Dallas.

MSDI - Magsat Data to Disk

This program is of major importance to Magsat data reduction. It reformats Magsat data and stores it in a disk file for subsequent plotting.

In addition to selecting a time window, the user must select either the "AL" or the "OR" mode. In the "AL" mode, the disk file is called MAGSAT.DAT and will contain all orbital observations within the time window followed by all the vector observations within the time window. In the "OR" mode, the disk file will be called SATORB.DAT and will contain orbital observations only.

Finally, in the "AL" mode, the user must select either regular density, whereby each disk file vector record will contain the average of 16 vector observations, or hexadecuple density whereby each vector

observation is written to disk.

Each record contains five four byte words. Integers written to disk are double precision.

Development of this program was made more difficult than necessary by irregularities in the tape format and by incomplete documentation of same. The following is a list of surprises and irritations.

(1) There is a four minute overlap at both ends of each orbital record, but there is no mention of this in the CSC manual.

(2) Orbital records begin on odd numbered hours plus 56 minutes. This makes day boundaries somewhat difficult to cross, especially when the manual says nothing about it.

(3) Some vector records begin at negative times, no documentation, of course.

(4) Some vector records are types 5, 6, 7 while others are types 8,9,10. The manual mentions 5,6,7 only.

(5) Some expected vector records are missing. This is mentioned in the manual but it would be better to fill in missing data with dummy data indicating that these data are missing. Orbital interpolation goes haywire when the observation time increment jumps from a small value to up to one complete revolution.

(6) Some scalar records are missing independently of the presence of vector records. This is also mentioned in the manual but it is bothersome to work around.

This software was authored by Ron Cook and was extensively modified by Dale Greer, both of UT-Dallas.

<u>RACTW - Request and Convert Time Window</u>

Called by MSDI this program requests the time window in year-month-day, hour-minute-second and converts it to modified Julian day and millisecond of day.

Author-Ron Cook

MTSTAT - Magsat Tape Status

Called by MSDI to report and act upon errors encountered while reading Magsat tapes.

Author-Ron Cook

SBFIBM-Swap Bytes from IBM

Called by MSDI to convert from IBM to DEC. single precision integer format.

Author-Ron Cook

CVTIBM-Convert IBM

Called by MSDI to convert from IBM to Dec. single precision floating point format. No source file for this one.

Author-Lou Wadel

2. Data Plotting Programs

ORBPLT-Orbit Plot

From the data in SATORB, DAT, ORBPLT plots the orbital section within 50 to 90 degrees north or south latitude, depending on user selection, in geomagnetic coordinates for each orbit in the file.

This program is used to find the start and stop times to be entered into MSPLT so that each vector data plot will cover the same area.

Author-Dale Greer

MSPLT-Magsat Plot

From the data in Magsat, MSPLT plots delta-B, the difference between the field measured and the field model (currently MGST680), the scalar difference is derived from the vectors.

MSPLT also plots the orbital section in geomagnetic coordinates for the time during which the measurements were taken. The orbit plot indicates northern or southern hemisphere through the drawing a solid or a dotted curve for each respectively.

Since it takes about a half second to process each vector record and to find the values of the four points to be plotted therefrom, the user is told how many points may be plotted from the chosen interval, and asked how many of these points are actually to be plotted. Points not plotted are simply skipped over and no averaging takes place since this is done to save time.

Author-Dale Greer

FIELDG-Field Generator

This program generates the field components from a model for subsequent subtraction from the measured values.

Author-unknown

Modified by Dale Greer

TOD-Time of Day

Called by MSPLT to get hour-minute-second of day from millisecond

of day.

Author-Ron Cook

2.1 Subroutines Called by the Plotting Programs Only

POSIT - Position

This subroutine is the main part in a package of three interdependent subroutines obtained from some U.S. Government source. POSIT was initially written to get the five orbital data points necessary for interpolation, send these to STIROB to accomplish such interpolation, then send these results to SATPOS to get the interpolated coordinates into latitude, longitude, and radius. Now, POSIT not only does that but also conditions coordinates for geomagnetic coordinate interpolation, flags northern or southern hemisphere, and crosses day boundaries.

Author-Unknown

Extensively Modified by Dale Greer

STIROB - ?

This program does the actual interpolation.

Author-Unknown

SATPOS-Satellite Position

SATPOS takes X, Y, Z coordinates from POSIT and converts to latitude, longitude, and radius. It can accomodate a rotating or a stationary coordinate system.

Author-Unknown

Modified by Dale Greer

TIME

Converts hour-minute-second to millisecond of day.

Author-Dale Greer

2.2 Subroutines Called by both the Tape Reading and Data Plotting Programs

YMDDOC-Year-month-day: day of century

Converts year-month-day to day of century.

Author-Ron Cook

DOCYMD-Day of Century: year-month-day

Converts day of century to year-month-day.

Author-Ron Cook

B. Modeling and Model Plotting Programs

The software described in this section was developed at the University of Texas at Dallas to model the magnetic fields that arise from distributed electrical currents flowing thorugh the near earth space environment. Care was taken to permit the calculation to be carried out with the fewest number of restrictions placed on the distribution of the input current system. All programs in this section were authored by Dale Greer of the University of Texas at Dallas.

CURDIS-Current Distribution

This program defines the model current distribution.

The model comprises a large number of current filaments assembled to simulate the Birkeland sheet currents. The filaments are like current carrying wires in that they have thickness, but unlike wires they have a smoothly varying cross-sectional current density, i.e., the density varies as the hyperbolic secant of the square of the

distance from the center. Such a distribution shall be referred to as Kurtic (from the Greek "Kurtos"-bulging or swelling.

The basic element of the model is the filament. The filaments are combined into loops and the loops are combined into cells. The base of the cell is in the ionosphere and comprises one north-south filament and one east-west filament. These filaments are sourced and sinked by the field-aligned filaments which are tangent to the magnetic field lines at the ionosphere. These filaments are straight and are three earth radii in length.

A more complex model, in which the field aligned filaments curved with the field lines all the way to the equatorial plane was tested. The increased complexity made a barely discernible difference in the final result and so was scrapped in favor of the former, simpler, and hence faster, model.

The current in each filament is defined at the base of the cell. The north-south and east-west components in the ionosphere give the current for the entire corresponding loop. The thickness of each filament is defined separately. These parameters are changed by modification of the source program.

The spatial parameters are defined interactively by the user. The user must give:

(1) The number of cell rings, i.e., the number of cells one would encounter on a trip from the pole to the equator.

(2) The number of cells per 360 degrees longitude.

(3) The latitudinal range in which the cells are distributed.

(4) The maximum radius of the filaments, in meters.

(5) The extent to which latitudinal compression takes place.

Finally, CURDIS puts the thickness of each filament, the current in each filament, the endpoints of the filaments, and the angles through which the filaments must be rotated in a disk file called DIS.DAT. The endpoints and angles are not given for each filament, rather advantage is taken of the symmetry of the model to decrease the size of the data file and speed up processing.

AMPLT-Ampere Plot

AMPLT shows the current flowing through the surface of a sphere just above the ionospheric currents for the Birkeland current model defined by CURDIS.

Each circle represents a field-aligned filament and encloses about 90 per cent of the kurtically distributed current.

Each line in one of these circles represents 10 K amp (current equals number of lines plus or minus 5 K amp).

CURPLT-Current Plot

CURPLT shows the current vectors in the ionosphere for the Birkeland current model defined by CURDIS.

BRKALC-Birkeland Calculate

BRKALC calls MAGMOD to find the current density and field components of the Birkeland current model defined by CURDIS at points on a circular orbit.

User must select the orbital altitude, the orbital inclination with the magnetic pole, the orbital angle with the dawn to dusk line, and the number of measurement points in this orbit.

The user must then elect to calculate the field of all the currents, the field of any one component bank of currents, all of the north-south currents, for example, are in one component bank or the field of all the currents, less any one component bank.

Finally, user must select either a polar pass, whereby the orbit will go from 50 degrees latitude western hemisphere to the same latitude eastern hemisphere, or an equatorial pass from 50 degress latitude north to 360 degress south in the eastern or western hemisphere.

MAGMOD-Magnetic Modeling

Called by BRKALC and 3DBRKC to evaluate the current density and field components of the Birkeland current model defined by CURDIS.

MAGMOD takes the end points of a filament as found by CURDIS, rotates it to its proper place, and calculates the field components and current density at point X,Y,Z given by the calling program.

BRKPLT-Birkeland Plot

BRKPLT plots the vaues found the BRKALC in XYZ, NEV, or SDV coordinates and shows the orbit.

3DBRKC- 3-D Birkeland Calculate

3DBRKC has the same function as BRKALC except that it creates a data set for a three dimensional plot with measurement points being on a sphere of radius "ALT" greater than that of the earth's and there is no provision for an equatorial data set.

3DPLT-3-D Plot

This program was not written by, but was modified by Dale Greer.

In its original form 3DPLT simply plotted a 3-D picture of an array. The form used here does the same but with perspective, zooming, and some interactive data conditioning included.

JBRKC- J Birkeland Calculate

JBRKC is like 3DBRKC except that it calls JBRKFN to find only the current density.

JBRKFN - J Birkeland Function

Is like MAGMOD except that it only calculates the current density.

JBRKP - J Birkeland Plot

JBRKP plots the findings of JBRKC as an eleven color field. It does this by sending direct commands to a Tektronix 4027. Eleven colors are derived from the eight available through the use of patterns.

BUFUN-Buffer Function

From JBRKP the PDP 11/45 sends commands to the 4027 so fast that the 4027 would crash and have to be turned off it is weren't for BUFUN. BUFUN just does a few calculations and has no effect on the program but to slow it down.

V. RECOMMENDATIONS FOR FURTHER WORK

This contract has demonstrated that a much more thorough analysis of the Magsat vector magnetic field observations when combined together with a versatile modeling technique of the various contributions to the Magsat measurements holds the promise of yielding valuable new insights on the subtle influences of space currents on main field and crustal anomaly studies. Further analysis of the Magsat data will also contribute fundamental new knowledge to our understanding of the electrodynamic coupling between the ionosphere and the magnetosphere. The low level of scientific effort allotted to the present study and its restriction to the demonstration of feasibility has not permitted the type of in depth analysis required to address the above problems. This contract has permitted the initial development of an inexpensive, versatile new tool whose ultimate application is still ahead.

A number of specific recommendations can be made for further studies:

1) Recognizing the universal time effect described in this report, analyze the space current perturbations during the specific quiet days that have been selected out of the Magsat data for anomaly and core field models. Apply the modeling procedure to remove the average quiet time space current contribution.
2) Perform an in-depth analysis of how the separate parts of the ionospheric and magnetospheric current systems show up in the vector Magsat measurements.
3) Use the modeling procedure to analyze the external and ionospheric current contributions at locations and altitudes relevant to proposed new magnetic field missions such as the

Geopotential Research Mission (GRM), low altitude tether satellite, and other free flying shuttle launched satellites.

4) There has been no consideration given to the altitude distribution of the ionospheric currents. All modeling and data reduction techniques developed to date have assumed that the horizontal ionospheric currents flow in a highly localized shell around 110 km altitude. Yet it is well known that there is an altitude distribution of the ionospheric conductivity and furthermore that the various terms of the conductivity tensor have different altitude profiles. These effects will beome much more important in low altitude magnetic field measuring satellite missions.

5) The problem of induction has not been treated in our model to any order. To the extent that currents induced in the earth by currents flowing overhead influence the magnetic field at Magsat, then we have not handled them. There are modifications that can be made to the model that will make correction for the effects of earth-induced currents.

6) Inversion: With respect to modeling the ionospheric and magnetospheric currents, one would like to be able to solve the inverse problem. That is, from the measurement of magnetic field, compute the responsible currents. This may not be possible from a single point satellite measurements, but see Item 7 below.

7) Ground level observations: Observations from a single satellite operating alone do not provide sufficient information

to solve for a unique system of currents. With some clever techniques to combine selected sets of single point Magsat measurements and by additionally incorporating ground based observations taken simultaneously over a large portion of the earth's surface we might just be able to overcome the non-uniqueness problems associated with single satellite measurements and find a true representation of the distributed external currents.

VI. SUMMARY AND CONCLUSIONS

This contract has demonstrated the feasibility of modeling the magnetic fields that arise from distributed currents in the near-earth geospace environment. The modeling procedure has been applied to the high latitude Magsat observations to show that substantial perturbations arise in the Magsat vector field, after subtraction of a spherical harmonic model of the earth's main field, that are due to currents flowing in the earth's ionosphere magnetosphere system. The contract has also involved data reduction and analysis of the Magsat data with respect to the potential effects of ionosphere-magnetosphere currents on the application of Magsat data to studies of magnetic crustal anomalies.

SPECIFIC RESULTS

1) Developed interactive data analysis software to permit graphical output of three-component magnetic field perturbations relative to a model geomagnetic field in different coordinate systems with interactive control of time base resolution.

2) Displayed and plotted Magsat vector measurements as perturbations relative to the Magsat spherical harmonic model magnetic field at latitudes above 50° geomagnetic latitude for all orbits during the first two months of the mission.

3) Developed a new forward modeling software procedure that determines the vector magnetic field due to distributed space currents.

4) Demonstrated that 3) could be accomplished efficiently, accurately, and with computational economy on a small (PDP 11/45) computer system.

5) Used the modelling procedure to determine the separate effects at

Magsat orbit due to the currents flowing:

a) in the ionosphere along the auroral oval in the E-W direction

b) in the ionsophere across the auroral oval in the N-S direction

c) along the magnetic field direction between the ionosphere and the magnetosphere.

6) Pointed out that periodicities of the Magsat orbit with respect to the auroral and ionospheric current systems can lead to contamination of anomaly and core field models by space current effects.

7) Recommended that dawn and dusk orbits be treated separately to evaluate the effects of 6)

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APPENDIX A

Abstractions of papers presented at scientific meetings:

A. A Method of Calculating Magnetic Fields Due to Systems of Distributed Currents, presented at American Geophysical Union, Spring Meeting, Baltimore, MD, May 25-29, 1981.

B. A Technique for Modeling the Magnetic Perturbations Produced by Field-Aligned Current Systems, presented at Fourth Scientific Assembly of IAGA, Edinburg, Scotland, August 3-15, 1981.

C. Modeling the High-Latitude Magnetic Field Produced by Distributed Ionospheric and Magnetospheric Currents, presented at the Theory Conference in Solar-Terrestrial Physics, Chestnut, Hill, MA, August 23-26, 1982.

D. Model Magnetic Field Perturbations at Magsat due to External Current Systems, presented at American Geophysical Union Spring Meeting, Baltimore, MD, May 30-June 3, 1983, Abstract: EOS, 64, 212 (1983).

Scientific Publications:

A. A Technique for Modeling the Magnetic Perturbations Produced by Field-Aligned Current Systems, D.M. Klumpar and D.M. Greer, Geophysical Research Letters, 9, 361, 1982.

APPENDIX A

A TECHNIQUE FOR MODELING THE MAGNETIC PERTURBATIONS PRODUCED BY FIELD-ALIGNED CURRENT SYSTEMS

D.M. Klumpar and D. M. Greer (Center for Space Sciences, University of Texas at Dallas, Richardson, Texas, 75080, U.S.A.)

This paper presents results of a computational procedure that utilizes various assumed distributions of ionospheric and field-aligned currents to model magnetic perturbations observed at high latitudes from the polar orbiting MAGSAT satellite. The highly sensitive vector magnetometers on MAGSAT repeatedly observed magnetic field perturbations on essentially every transit of the high latitude ionosphere. These perturbations, with field components lying predominantly in the magnetic East-West direction, are customarily viewed as the signatures of oppositely directed paired sheets of electrical current flowing parallel to the geomagnetic field. These paired current sheets are typically regarded as being highly restricted in latitudinal extent and elongated in magnetic longitude. The model developed under this research utilizes a computationally fast and mathematically simple technique that allows the magnetic field of a distributed current system to be calculated by representing such a system by an arbitrary number of hypothetical linear current elements. The facility of the technique derives from the use of an analytic expression for the magnetic field of a linear current element having an extended and smoothly varying cross sectional current density; thus eliminating unwanted discontinuities. Magnetic perturbations typical of those encountered at auroral latitudes by MAGSAT are produced by the model when realistic current configurations are chosen. Direct comparisons between the model field perturbations and those measured by the MAGSAT magnetometers permit more refined models of the Birkeland currents to be developed.

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2. ER

3. N. Fukushima, S. Matsushita

4. - (a) Oral presentation

Submitted to Fourth Scientific Assembly of IAGA, Edinburgh, August 3-15, 1981

APPENDIX A

ABSTRACT

A METHOD OF CALCULATING MAGNETIC FIELDS
DUE TO SYSTEMS OF DISTRIBUTED CURRENTS

D.M. Greer
D.M. Klumpar, (both at: Center for Space Sciences, University of Texas at Dallas, Box 688 Richardson, Texas, 75080)

Electrical currents in the ionosphere and in the magnetosphere produce large amplitude magnetic field perturbations that are detected by the highly sensitive magnetometers on the polar orbiting MAGSAT satellite. THis paper describes a computationally fast and mathematically simple method that has been developed and applied to modeling the magnetic field produced by the Birkeland current system. The technique allows the magnetic field of a distributed current system to be calculated by representing such a system with an arbitrary number of hypothetical linear current elements. The facility of this method derives from the use of an analytical expression for the magnetic field of a straight current filamenty having an extended and smoothly varying current density. The cross sectional current density profile of such a filament looks somewhat like a swuare wave pulse, of arbitrary width, with rounded corners. Thus the system is free from unwanted discontinuities and the field component in any direction and at any point in the model space is easily calculated. Magnetic perturbations typical of those encountered at auroral latitudes by MAGSAT are produced by the model when realistic current configurations are chosen.

APPENDIX A

MODELING THE HIGH-LATITUDE MAGNETIC FIELD PRODUCED BY DISTRIBUTED IONOSPHERIC AND MAGNETOSPHERIC CURRENTS

D. M. KLUMPAR, (Center for Space Sciences, The University of Texas at Dallas, Box 688, Richardson, Texas, 75080)

D.M. GREER

The magnetic field disturbances resulting from distributed currents in the high latitude ionosphere and from the Birkeland currents, which extend outward into the magnetosphere, are computed using a highly efficient computational technique that has recently been developed. Using this technique the magnetic effects of the large-scale distributed Birkeland, Hall, or Pedersen currents can be computed independently to ascerrtain their separate contributions to the magnetic perturbations typically measured by magnetic observatory arrays on the ground or by satellite borne magnetometers. Use of this technique illustrates the complexity of the many contributions from various currents that combine to produce the net magnetic disturbance that is measured. Such modelng analysis provides the basis for improved interpretation of ground and satelite magnetic observations in terms of the responsible currents. Such improvements will subsequently lead to more realistic representations of the true horizontal and field-aligned current systems than is available from the customary "equivalent current representation" and hence to a better understanding of magnetospheric dynamics. We present a set of model calculations of the magnetic vector components arising from an assumed ionospheric and Birkeland curent system and compare the predicted magnetic signature to that typically measured from low altitude polar orbiting satellites and from high latitude magnetometer chains.

APPENDIX A

Model Magnetic Field Perturbations at Magsat due to External Current Systems

D. M. GREER and D. M. KLUMPAR (Center for Space Sciences, The University of Texas at Dallas, Richardson, Texas 75080)

Significant magnetic field perturbations due to currents in the ionosphere-magnetosphere system are observed on virtually every Magsat orbit over the high latitude ionosphere. We utilize a model of distributed currents consisting of the horizontal ionospheric currents and field-aligned (Birkeland) currents to compute the perturbation magnetic fields along Magsat orbits. The computer code models the distributed currents by decomposition into a large number of linear, finite cross section current elements for which the magnetic field can readily be computed. The perturbation field at each point in space due to the entire distributed current system is then the vector addition of the appropriate contributions from each current element in the system. We compare the model derived magnetic perturbations with those deduced from actual Magsat measurements to iteratively determine the distribution of ionospheric and Birkeland currents for particular Magsat orbits.

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GEOPHYSICAL RESEARCH LETTERS, VOL. 9, NO. 4, PAGES 361-364, APRIL 1982

APPENDIX A

A TECHNIQUE FOR MODELING THE MAGNETIC PERTURBATIONS PRODUCED BY FIELD-ALIGNED CURRENT SYSTEMS

ORIGINAL PAGE IS OF POOR QUALITY

D.M. Klumpar and D.M. Greer

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Abstract. A computational procedure is introduced for calculating the magnetic fields produced by virtually any distributed system of electrical currents. This procedure is being applied to the modeling of magnetic fields produced near the earth and on its surface by horizontal currents flowing in the ionosphere and by the so-called Birkeland currents flowing along the geomagnetic field at high magnetic latitudes. This report describes briefly the principles that underlie the technique and illustrates the results obtained when the model is applied to the interpretation of perturbation fields being measured by the polar-orbiting magnetic fields satellite (MAGSAT). Even for a very simple assumed current distribution we calculate magnetic field residuals whose large-scale features are similar to those deduced from MAGSAT measurements. A predominately sunward magnetic perturbation is obtained over the region poleward of the Region 1 current system as a natural consequence of balanced Region 1 and Region 2 currents. The model predicts the existence of low-latitude magnetic effects of auroral currents that represent potential sources of error for spherical harmonic representations of the geomagnetic field.

Introduction

The magnetic field measured from near-earth orbit, although dominated by the earth's main magnetic field, contains significant components that arise from electrical currents flowing in the ionosphere-magnetosphere system. In particular, at high latitudes near the auroral oval, currents flowing parallel to the geomagnetic field may cause perturbations in the locally measured magnetic field in excess of 1500 nT directed primarily transverse to the main geomagnetic field. Such field-aligned current signatures were first measured from satellite 1963-38C and reported by Zmuda et al. [1966, 1967]. Since that time magnetometers on a number of low-altitude satellites (TRIAD, ISIS, AE-C, S3-2) have been used to infer the nature of the magnetic perturbations arising from field-aligned currents [e.g., Iijima and Potemra, 1976a,b; Klumpar et al., 1976; McDiarmid et al., 1978a,b; Klumpar, 1979; Bythrow et al., 1980, 1981; Doyle et al., 1981; and others]. In 1979 a dedicated magnetic fields satellite was launched to make the first global vector survey of the geomagnetic field.

The magnetic fields satellite, MAGSAT, was placed in a near-earth sun-synchronous orbit with the objectives of making precise magnetic field measurements to accurately describe the earth's main magnetic field and to map, on a global basis, the fields caused by sources in the earth's crust [Langel, 1979]. It was recognized early in the program that the sensitive magnetometers would also measure the magnetic field produced by currents flowing in the ionosphere-magnetosphere system external to earth and that at some locations and times these external effects would even mask the crustal anomaly fields.

Analyses of these externally caused magnetic perturbations in terms of the responsible currents have generally assumed a highly idealized, local system of paired, infinitely long, planar, parallel current sheets oriented perpendicular to the satellite trajectory. Kisabeth [1979] took a major step towards eliminating these restrictive geometrical assumptions by devising a computational technique to determine the magnetic perturbations that would arise from more general distributions of currents. The present work represents a new effort to model the magnetic perturbations resulting from distributed electrical currents flowing in space around the earth. To that end a method has been developed for calculating the magnetic field at any point in space due to an assumed spatial distribution of electric currents. This paper briefly describes the computation technique and discusses several important aspects of the magnetic perturbations that result from a simple large-scale Birkeland and ionospheric current system resembling that previously deduced from the large body of near-earth magnetic field measurements. We conclude by comparing signatures derived from MAGSAT measurements with those predicted by the computational technique.

Several aspects of the field perturbations derived from the modeled large-scale current system raise questions about commonly accepted interpretations of satellite-borne magnetic observations. They are:

1. For a balanced Birkeland current system in which all of the field-aligned current closes in the N-S direction between the Region 1 and Region 2 field-aligned current sheets, there still exists a sunward-directed magnetic perturbation in the region poleward of the Region 1 currents. Thus, contrary to some suggestions, a polar "top-hat" field distribution does not necessarily imply a net field-aligned current in the Region 1 current system.
2. Significant magnetic field perturbations due to high latitude currents extend to latitudes well below those normally associated with the auroral zone.
3. The existence of a positive perturbation in the sunward component of the magnetic field over the polar cap does not require a cross polar cap current, but rather arises as a natural consequence of a balanced classical Region 1 and Region 2 Birkeland current system.

The Field Modeling Technique

The magnetic field computation technique is based upon the additive properties of vector fields. In general, the field vector at a point in space is the vector sum of the vector components arising from all of the elemental field sources in the universe. In the present case, the magnetic field at a point is computed by summing the contributions of all of the assumed currents that exist everywhere in space. The assumed current distribution is modeled by decomposing the actual current distribution into an arbitrary number of finite length current elements. The technique itself relies upon the use of an analytical expression for the magnetic field of a straight current carrying filament having an extended and smoothly varying cross-sectional current density. The cross-sectional current density profile looks somewhat like a square wave pulse with rounded corners. The use of such a platykurtic distribution has been found to eliminate discontinuities that exist in a square wave representation and allows for easy calculation of the vector magnetic field at any point in the world space.

The total current distribution to be calculated is represented by an arbitrary number of these finite length current elements. Typically several hundred such current elements are used to represent the horizontal and field-aligned current distribution over the high latitude ionosphere. By a suitable summation of the field at each point due to the contributions from all current elements, the magnetic field may be calculated anywhere, such on the earth's surface or along a satellite orbit.

As an illustration of the technique, we show in Figure 1 a simple, hypothetical, ionospheric current distribution that is characterized by dominant north-south currents. A large-scale eastward electrojet current flows from noon across the dusk hemisphere toward midnight while a westward electrojet current is directed through the dawn hemisphere from noon to midnight. All currents are confined to a shell running between 60° and 76° latitude. This horizontal current system requires, for continuity, that there be accompanying field-aligned currents, which are shown in Figure 2. The circles represent the locations of possible field-aligned current elements and the cross hatching represents the direction and relative magnitude of the field-aligned

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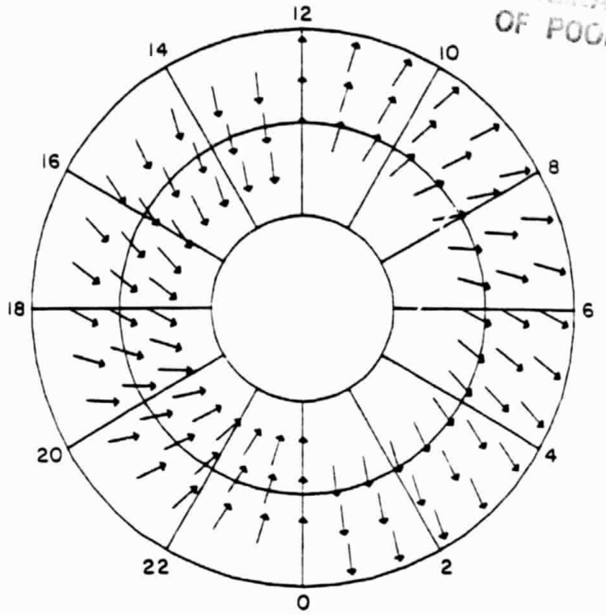
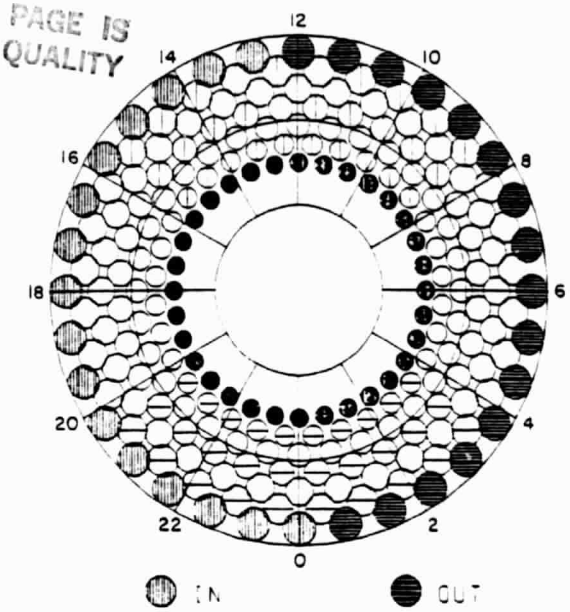


DISTRIBUTION OF IONOSPHERIC CURRENTS

Figure 1. High latitude distribution of horizontal ionospheric currents plotted on a latitude versus local time coordinate grid. All horizontal currents are constrained to flow inside a channel between 60° and 76° latitude.



DISTRIBUTION OF FIELD ALIGNED CURRENTS

Figure 2. The distribution of field-aligned currents required to maintain current continuity with the horizontal currents shown in Figure 1.

currents. Vertical hatching depicts the presence of an inward current, which is seen to exist at low latitudes in the post-noon to midnight sector and at high latitudes in the morning hemisphere. Horizontal hatching indicates the outward current at high latitudes on the evening hemisphere and at low latitudes in the morning hemisphere. These high and low latitude field-aligned currents represent the Region 1 and Region 2 currents deduced by Iijima and Potemra [1976a,b] from a study of the TRIAD data.

In addition to the sheet-like currents discussed above, the chosen horizontal current distribution requires that there be an additional downward current near noon and an upward current near midnight. These currents partially feed into the eastward and westward electrojets that flow across the dawn and dusk hemispheres in Figure 1.

The primary question we seek to answer is, what are the magnetic fields produced by such a current system? Figure 3 displays the results of the computation in the upper three panels as latitude profiles of three components of the magnetic field that would be measured at a satellite at 450 km altitude moving along the dusk to dawn meridian. The cartwheel plot at the upper right depicts the path along which the field is computed. The bottom panel displays the field-aligned current density profile as a function of latitude along the satellite orbit, which, as anticipated from the previous figure, passes through only the classical Region 2 and Region 1 Birkeland currents. As expected, the major perturbation appears in the East-West component with the steepest gradients occurring at the location of the local field-aligned currents.

Smaller, but still significant, magnetic field contributions are found in the region equatorward of the low latitude termination of current flow. The magnetic field strength at 50° latitude, a full 10° of latitude equatorward of the auroral currents, are of the order of 10 to 20 nT and decay only slowly with decreasing latitude. The presence of such mid-latitude magnetic effects in satellite measurements may, if not properly attributed to the external current system, contribute to errors in a proper spherical harmonic representation of the main magnetic field. Concentrating now on latitudes poleward of the high latitude currents, it is apparent that there is again a significant magnetic perturbation due to the modeled currents. This so-called "polar top-hat" field perturbation is directed primarily sunward. This model shows that it arises as a natural consequence of a balanced current system in which the upward and downward currents along a meridian are equal.

Such level shifts observed in satellite data have in the past been interpreted as evidence for a net field-aligned current in the Region 1 system [Sugiura and Potemra, 1976], or as a result of cross polar cap currents [Fujii et al., 1981]. Finally, we note that the modeled currents also produce a notable perturbation in the vertical component of B. Such an effect has been detected in the MAGSAT data.

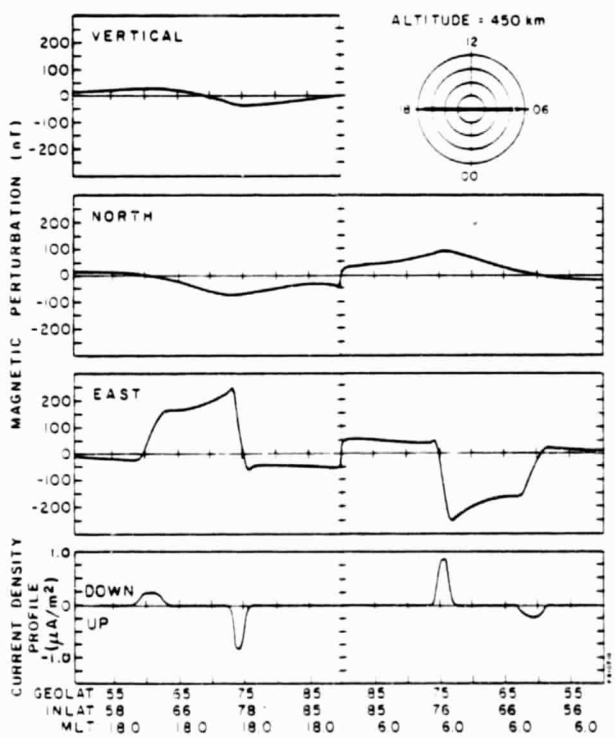


Figure 3. Computed latitude profiles of the vector magnetic field perturbations that would be observed by a magnetometer on a satellite moving along the dusk-dawn meridian at 450 km altitude as a result of the currents shown in Figures 1 and 2.

In Figure 4 are shown, for the same current distribution, the magnetic field profiles along a somewhat different orbit where the satellite passes on the dayside of the pole. The main features of the magnetic profiles observed in the dusk-dawn meridian are preserved with the primary difference being a reduction in amplitude of the N-S component and a widening of the E-W profile, as the satellite makes a more oblique pass through the current system.

Although only profiles at satellite altitude have been shown, the modeling procedure described here also allows the field components to be calculated on the surface of the earth. Such a model will permit further understanding of the external sources of the magnetic fields measured on the ground and in space and, in particular, of the complex magnetospheric-ionosphere electrical circuit.

Comparison with MAGSAT Data

From the vector magnetic measurements made by MAGSAT it is possible to derive a difference field by subtracting a model representation of the earth's main magnetic field from the measured field. This difference field is presumably the resultant perturbation that arises from the combined effects of externally produced fields due to currents in space and induced in the earth, crustal anomalies, and inaccuracies in the spherical harmonic model representation of the core field. If in the first approximation we choose to ignore the latter two contributions to the difference field because they are small, and assume a steady state external current system, the difference field will represent only the effects of external currents. Figure 5 shows such a difference field for a dusk to dawn MAGSAT pass over the northern latitudes on November 13, 1979. In producing this difference field a thirteenth degree and order spherical harmonic representation of the main magnetic field referred to as the MGST (6/80) model [Langel et al., 1980] was used. For this orbit the satellite passes just to the dayside of the dusk to dawn meridian. The largest deviations from the model, up to 950 nT in the East-West component, occur as the satellite passes over the dusk auroral oval between 10:56 and 10:59 UT. A deviation of approximately one-third of the E-W component is also present in the N-S component. Furthermore the N-S component has a 130 nT residual deviation extending down below 41° geographic latitude. The absence of such a low-latitude residual in the E-W component is somewhat at variance with the predictions of the model discussed in the previous section. Two possible explanations may account for this variance. The first is that the auroral current model discussed in the previous section may not accurately portray the real currents during this pass, and that the real current system is producing no E-W field component at low latitude. A second possibility is that the 13th order spherical harmonic expanison has been contaminated by the low latitude fields due to polar currents and as a result has these effects built-in as a part of the main geomagnetic field. The actual resolution of the discrepancy may rest in some combination of these two possibilities and will be one of the objectives of further modeling efforts.

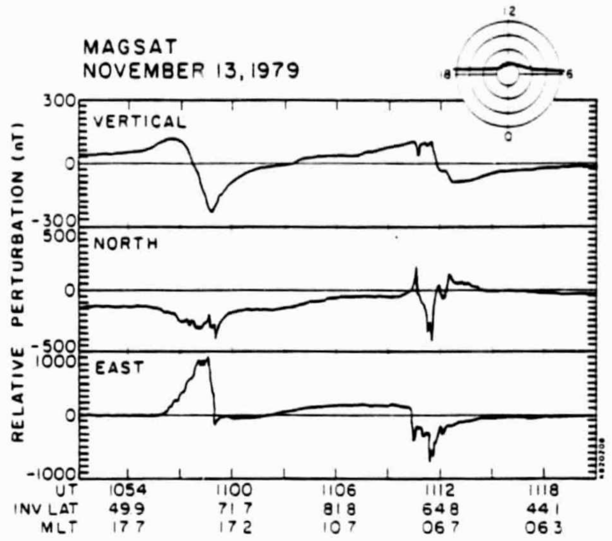


Figure 5. Measured difference fields along a MAGSAT orbit on November 13, 1979. All three components are plotted relative to the MGST (6/80) field model of Langel et al. [1980].

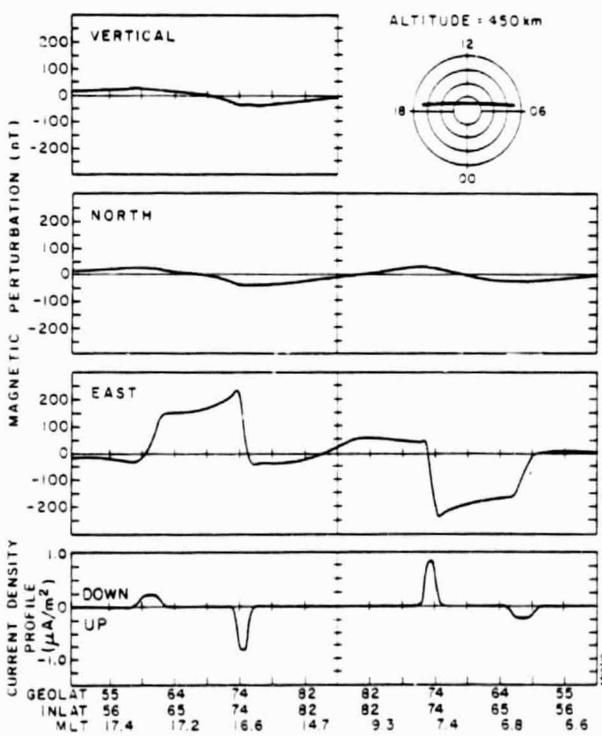


Figure 4. Similar to Figure 3 for a satellite orbit passing on the dayisde of the dusk-dawn meridian as shown in the upper right hand corner.

Further comparisons of this MAGSAT difference plot with the perturbations calculated from the simple model and shown in Figure 4 reveal gross similarities in the large-scale features and substantial differences in details. The latter arise from small-scale variations in the actual current sytem that were present during the MAGSAT pass shown in Figure 5 for which no attempt to model has been made in the current distribution discussed here. This comparison serves to illustrate the complexities that exist in the real Birkeland current system.

Conclusion

A general calculational procedure has been developed to compute the magnetic field perturbations arising from distributed ionospheric and ionosphere-magnetosphere coupling currents. A simplified current distribution has been chosen to illustrate the technique and the resulting magnetic perturbations have been compared to actual magnetic perturbations measured from MAGSAT. The balanced Birkeland current system produces non-negligible low-latitude magnetic field perturbations. A sunward magnetic perturbation is also produced at latitudes poleward of the high latitude current sheet.

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C<><><><><><><><><><><><><><><><><><><><><><><><><><><><><><><><><><><><><><>D
C
C     MSMDI =  MONITOR PROGRAM FOR EXECUTION OF MAGSAT TAPE
C          READ PROGRAMS.
C        1980 APR 18 R.W.COOK
C             REVISED 1982 SEP 30 D.M.GREER
C     THIS IS THE MONITOR ROUTINE WHICH TRANSLATES INSTRUCTIONS FROM
C     THE CONSOLE TO COMPUTER OPERATIONS ON DATA FROM MAGSAT.
C
C<><><><><><><><><><><><><><><><><><><><><><><><><><><><><><><><><><><><><><>D
C
      BLOCK DATA
      INTEGER*2 IMDS(12),IDPM(12),DOWTAB(7)
      INTEGER*4 MOYTAB(12)
      COMMON IMDS,IDPM,MOYTAB,DOWTAB
      DATA IMDS/000,031,059,090,120,151,181,212,243,273,304,334/
      DATA IDPM/031,028,031,030,031,030,031,031,030,031,030,031/
      DATA MOYTAB/'JAN ','FEB ','MAR ','APR ','MAY ','JUN ','JUL ',
     1        'AUG ','SEP ','OCT ','NOV ','DEC '/
      DATA DOWTAB/'SU','MO','TU','WE','TH','FR','SA'/
      END
```

Appendix B

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```
      PROGRAM MSMDT
C
      LOGICAL*1 AINS(80),ACTOD(8),BCTOD(8)
      INTEGER*2 IMDS(12),IDPM(12),DOWTAB(7)
      INTEGER*4 MOYTAB(12)
      INTEGER*4 IDOC,ICDOC,ICMJD
      REAL*4 BINS(1)
C
      COMMON IMDS,IDPM,MOYTAB,DOWTAB
      COMMON /MON/MOSEQ,AINS
C                                                                D
      EQUIVALENCE (AINS(1),BINS(1))
C
C **** TELL USER PRESENT DATE AND TIME
C
10000 ICCEN=19
      CALL IDATE(IMOY,IDOM,IYOC)
      CALL TIME(BCTOD)
      DO 10019 I=1,8
      ACTOD(I)=BCTOD(I)
10019 CONTINUE
      CALL YMDDOC(IYOC,IMOY,IDOM,IDOY,IDOC,IDOW)
      ICYOC=IYOC
      ICMOY=IMOY
      ICDOM=IDOM
      ICDOY=IDOY
      ICDOC=IDOC
      ICDOW=IDOW
      ICMJD=ICDOC+15020
      TYPE 00100,ICCEN,ICYOC,MOYTAB(ICMOY),ICDOM,DOWTAB(ICDOW),ICDOY,
     1ICDOC,ICMJD
C
10100 MOSEQ=0
C
C **** CHECK FOR 'EXIT', 'RESTART' BEFORE GOING TO APPROPRIATE RESPONSE
C **** PROCESSING SECTIONS.
C
10020 TYPE 00110
10021 ACCEPT 00001,AINS
      MOSEQ=MOSEQ+1
C
      IF(BINS(1).EQ.'EXIT')GO TO 90000
      IF(BINS(1).EQ.'REST')GO TO 10000
C
10200 IF(AINS(1).EQ.'D')GO TO 20000
      GO TO 10020
C
20000 CALL MSDI
      GO TO 10000
C
90000 STOP
C
C<><><><><><><><><><><><><><><>FORMAT STATEMENTS<><><><><><><><><><><><><>D
00001 FORMAT(80A1)
00100 FORMAT( '0DATE:',2I2,1X,A3,1X,I2,1X,A2,', DOY:',I3,
     1', DOC:',I5,', MJD:',I5,
```

```
        2/,' MAGSAT - GEOMAGNETIC FIELD ORBITAL DATA ',//)
0038    00110 FORMAT(' SELECT ONE OF THE FOLLOWING OPTIONS:',
        1/,'         ''DI'' TO REFORMAT MAGSAT DATA TO DISK',
        2/,'         ''EXIT'' TO TERMINATE EXECUTION OF PROGRAM MSMON')
      C<><><><><><><><><><><><><><><><><><><><><><><><><><><><><><><><><><><><><><><>D
0039          END
```

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```
C<><><><><><><><><><><><><><><><><><><><><><><><><><><><><><><><><><><><><>D
C
C     SUBROUTINE MSDI - TRANSFERS MAGSAT DATA FROM TAPE TO DISK
C          1980 APR 18 - R.W.COOK
C          REVISED 1982 SEP 30 - D.M.GREER
C
C<><><><><><><><><><><><><><><><><><><><><><><><><><><><><><><><><><><><><>D
C
      SUBROUTINE MSDI
C
      LOGICAL*1 AINS(40)
      LOGICAL*1 ISEOP,ARRAY(4122)
      LOGICAL*1 NAME(11), NAME1(11), NAME2(11)
C
      INTEGER*2 NV(3),IMDS(12),IDPM(12)
C
      INTEGER*4 IARRAY(1030),IDOC
      INTEGER*4 IBMJD,IBDOC,IBHOD,IBSOD,IBMSOD
      INTEGER*4 IEMJD,IEDOC,IEHOD,IESOD,IEMSOD
      INTEGER*4 IOMJD,IOMSOD,IODELT
      INTEGER*4 JOMJD,JOMSOD,JMSDI
      INTEGER*4 IVMJD,IVMSOD,IVOFFT
      INTEGER*4 JVMJD,JVMSOD,JVMSD2
      INTEGER*4 NO,NMEAS,KK,NM
      INTEGER*4 IBHMS,IEHMS,IORB
C
      REAL*4 BINS(1),RARRAY(1030),RVSTAT(3,3),VECT(1024,3)
C
      COMMON IMDS,IDPM
      COMMON /MON/MOSEQ,AINS
      COMMON /SDTG/IBYOC,IBMOY,IBDOM,IBDOW,IBDOY,IBDOC,IBMJD,
     1              IBHOD,IBMOH,IBSOM,IBSOD,
     2              IEYOC,IEMOY,IEDOM,IEDOW,IEDOY,IEDOC,IEMJD,
     3              IEHOD,IEMOH,IESOM,IESOD
C
      EQUIVALENCE (AINS(1),BINS(1))
      EQUIVALENCE (IARRAY(1),ARRAY(1)),(RARRAY(1),ARRAY(1))
      EQUIVALENCE (ITYP,ARRAY(1))
C
      DATA NAME1 / 'M','A','G','S','A','T','.','D','A','T','0' /
      DATA NAME2 / 'S','A','T','O','R','B','.','D','A','T','0' /
C
C***************************************************************************)
C
11111 TYPE 00100
C
10000 MOSEQ=1
      MSEQ=1
      GO TO 10100
10010 ACCEPT 00001,AINS
      IF(BINS(1).EQ.'EXIT')GO TO 90000
      IF(BINS(1).EQ.'REST')GO TO 10000
C
      GO TO (10100,10200,10300),MOSEQ
C
C **** GET TIME WINDOW
```

```
C
10100 CALL RACTN
      IF(BINS(1).EQ.'EXIT')GO TO 90000
      MOSEQ=2
C
      IBMSOD=IBSOD*1000
      IEMSOD=IESOD*1000
      NVEC=0
      NAXIS=0
      NREC=0
      NO=0
      NMEAS=0
      KK=3
      JMSD1=863400000
      IORB=0
      IGN=64
      RGN=16.
      NAME(11)=0
C
C*****************************************************************************)
C
C **** REQUEST AND ACCEPT AL FOR ALL DATA, OR FOR ORBIT ONLY
C
10200 ISEOP='A'
      GO TO (10210,10220),MSEQ
10210 TYPE 00120
      MSEQ=2
      GO TO 10010
10220 IF(AINS(1).EQ.'A'.AND.AINS(2).EQ.'L')GO TO 10225
      IF(AINS(1).EQ.'O'.AND.AINS(2).EQ.'R')GO TO 10225
      GO TO 10210
C
C **** GET DENSITY
C
10225 TYPE 00130
      ACCEPT 00200, IDEN
      IF (IDEN.EQ.1) IGN=1024
      IF (IDEN.EQ.1) RGN=1.
      ISEOP=AINS(1)
      MSEQ=1
      MOSEQ=MOSEQ+1
C
C **** IF USER SELECTS AL, OPEN MAGSAT.DAT,
C **** IF USER SELECTS OR, OPEN SATORB.DAT
C
      IF (ISEOP.EQ.'A') GO TO 10226
      IF (ISEOP.EQ.'O') GO TO 10227
10226 DO 10230 I=1,10
        NAME(I)=NAME1(I)
10230 CONTINUE
      GO TO 10228
10227 DO 10231 I=1,10
        NAME(I)=NAME2(I)
10231 CONTINUE
10228 OPEN(UNIT=4,NAME=NAME,TYPE='NEW',
     1FORM='UNFORMATTED',ACCESS='DIRECT',RECORDSIZE=8)
```

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```
      C
      C***********************************************************************)
      C
      10300 IU=2
            ILUN=3
            IP=0
            IBPI=0
            NB=4122
      C
      C **** BEFORE WRITING USER SELECTED PARAMETERS ONTO DISK,
      C **** ENCODE YEAR, MONTH, DAY AND HOUR, MINUTE, SECOND
      C **** FOR ECONOMICAL RECORD LENGTH
      C
            RBYMD=IBYOC*10000.+IBMOY*100.+IBDOM
            REYMD=IEYOC*10000.+IEMOY*100.+IEDOM
            IBHMS=IBHOD*10000 +IBMOH*100 +IBSOM
            IEHMS=IEHOD*10000 +IEMOH*100 +IESOM
            WRITE(4'2)RBYMD,IBDOC,IBMJD,IBHMS,IBMSOD
            WRITE(4'3)REYMD,IEDOC,IEMJD,IEHMS,IEMSOD
            IORB=2*(IEMSOD-IBMSOD+86400000*(IEMJD-IBMJD))/60000 + 2
            JVMSD2=IBMSOD
      C
      10311 MTIE=0
            CALL SETPRM(IU,IP,IBPI,ILUN,IS)
            CALL MTSTAT(ILUN,IS)
            IF(IS.NE.0)GO TO 90000
      C
      C***********************************************************************)
      C
      C **** READ TAPE, SWITCH BYTES, PROCEED TO TYPE PROCESSING
      C
      12000 IB=NB
            MTIE=1
      12010 MTRC=0
      12011 CALL READI(IU,IB,ARRAY,IS,NBR)
            IF(MTRC.GT.10)GO TO 12010
            IF(IS.EQ.0)GO TO 12030
            CALL MTSTAT(ILUN,IS)
            GO TO (12015,12010,90000,90000,90000,90000,90000,90000,90000,
           A90000,90000,90000),IS
      12015 MTRC=MTRC+1
            GO TO 12011
      12030 NREC=NREC+1
            CALL SBFIBM(ARRAY(1),ARRAY(1),NBR)
            NTYP=ITYP/256
      12032 IF(NTYP-1)13000,12000,14000
      C
      C***********************************************************************)
      C
      C **** ORBIT RECORD
      C **** 1 POSITION/MINUTE, (128 MIN/RECORD, 7680 SECONDS/RECORD)
      C
      13000 N=6
            CALL SHFIBM(IARRAY(02),IARRAY(02),N)
      C
      C **** TAPE SEARCH ORBIT DATE AND TIME FILTER
```

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```
          C
          C **** TWO DAYS AWAY - KEEP READING
          C
0106              IF(IARRAY(02)+1.LT.IBMJD)GO TO 12000
0107              IF(IARRAY(02)-IBMJD) 13001,13002,13003
          C
          C **** ONE DAY AWAY - IF DESIRED TIME FALLS WITHIN THE DAY OVERLAP
          C **** RECORD, PROCEED TO PROCESSING
          C
0108      13001 IF(IARRAY(03)+IARRAY(04)*128-86400000.LE.IBMSOD) GO TO 12000
0109              GO TO 13010
          C
          C **** DESIRED DAY - DESIRED TIME?
          C
0110      13002 IF(IARRAY(03)+IARRAY(04)*128.LE.IBMSOD) GO TO 12000
0111              GO TO 13010
          C
          C **** LAST DAY? - LAST TIME?
          C
0112      13003 IF(IARRAY(02).LT.IEMJD) GO TO 13010
0113              IF((IARRAY(02).EQ.IEMJD).AND.(IARRAY(03).LT.IEMSOD)) GO TO 13010
0114              GO TO 90000
          C
0115      13010 IOMJD=IARRAY(02)
0116              IOMSOD=IARRAY(03)
0117              IODELT=IARRAY(04)
0118              N=770
0119              CALL CVTIBM(RARRAY(05),N)
0120              ROREFT=RARRAY(05)
0121              ROGHOU=RARRAY(06)
          C
0122              KK=KK+1
0123              IF (KK.GT.4) GO TO 13100
0124              WRITE(4'KK)ROREFT,ROGHOU,ROREFT,ROGHOU,ROREFT
          C
          C **** DISK WRITE ORBIT DATE AND TIME FILTER
          C
0125      13100 I=0
0126      13110 JOMJD=IOMJD
0127              JOMSOD=IOMSOD+I*IODELT
0128              IF(JOMSOD.LT.86400000)GO TO 13120
0129              JOMJD=JOMJD+1
0130              JOMSOD=JOMSOD-86400000
0131      13120 IF(JOMJD.LT.IBMJD)GO TO 13590
0132              IF(JOMJD.GT.IEMJD)GO TO 12000
0133              IF(JOMJD.NE.IBMJD)GO TO 13130
0134              IF(JOMSOD.LT.IBMSOD)GO TO 13590
0135      13130 IF(JOMJD.LT.IEMJD)GO TO 13200
0136              IF((JOMSOD/60000).GT.(IEMSOD/60000))GO TO 12000
          C
          C **** SKIP OVERLAP FROM LAST ORBITAL RECORD
          C
0137      13200 IF (JMSD1.GE.86340000) GO TO 13300
0138              IF (JOMSOD.LE.JMSD1) GO TO 13590
0139              IF ((JOMSOD-JMSD1).GT.6060000) GO TO 13590
          C
```

```
C **** WRITE ORBIT DATA TO DISK
C ****  RARRAY((J-1)*128+II), J=1,3 = X,Y,Z COORDINATES
C ****  RARRAY(II) = INVARIANT LATITUDE
C ****  RARRAY(II+128) = GEOMAGNETIC TIME
C ****  RARRAY(II+256) = DIPOLE LATITUDE
C
13300 NO=NO+1
      NN=3+2*NO
      II=7+I
      WRITE(4'NN)NO,JOMSOD,(RARRAY((J-1)*128+II),J=1,3)
      NN=NN+1
      II=7+I+3*128
      WRITE(4'NN) NO,JOMSOD,RARRAY(II),RARRAY(II+128),RARRAY(II+256)
      JMSDI=JOMSOD
13590 I=I+1
      IF(I.LT.128)GO TO 13110
      GO TO 12000
C
C@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@)
C
C **** SEARCH FOR DESIRED VECTOR RECORD
C **** OR SKIP TO NEXT ORBITAL RECORD IF 'OR' WAS SELECTED
C
14000 IF(ISEOP.EQ.'OR')GO TO 12000
      IF(NTYP.GT.4)GO TO 14011
      TYPE 00903, NTYP
      GO TO 12000
14011 NVEC=NVEC+1
14020 N=4
      CALL SHFIBM(IARRAY(2),IARRAY(2),N)
      N=2
      CALL CVTIBM(RARRAY(04),N)
C
C **** TAPE SEARCH VECTOR DATE AND TIME FILTER (SEE ORBIT DTF ABOVE)
C
      IF(IARRAY(02)+1.LT.IBMJD)GO TO 12000
      IF (IARRAY(02)-IBMJD) 14101,14102,14103
14101 IF (IARRAY(03)+RARRAY(04)*1024-86400000.LT.IBMSOD) GO TO 12000
      GO TO 14110
14102 IF (IARRAY(03)+RARRAY(04)*1024.LT.IBMSOD) GO TO 12000
      GO TO 14110
14103 IF (IARRAY(02).LT.IEMJD) GO TO 14110
      IF ((IARRAY(02).EQ.IEMJD).AND.(IARRAY(03).LT.IEMSOD)) GO TO 14110
      GO TO 90000
14110 IF(NTYP-1)90000,12000,16000
C
C@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@)
C
C **** VECTOR RECORD PROCESSING
C **** 1024 SAMPLES/(AXIS RECORD), 1 AXIS/RECORD.
C
C **** VECTOR RECORDS ONLY
C
16000 IF (NTYP.GT.10) GO TO 12000
      NAXIS=NAXIS+1
C
```

```
C **** SOME VECTOR RECORDS ARE NTYP=5,6,7 - OTHERS ARE 8,9,10
C
            IF (NTYP.LT.8) NTYP=NTYP+3
            IAXIS=NTYP-4
            IF(IAXIS.GT.3)IAXIS=IAXIS-3
            IF(IAXIS.NE.NAXIS)GO TO 90000
C
            IVMJD=IARRAY(02)
            IVMSOD=IARRAY(03)
            RVDELT=RARRAY(04)
            IVOFFT=RARRAY(05)*1000.0
            IVMSOD=IVMSOD+IVOFFT
            N=1024
            CALL CVTIBM(RARRAY(07),N)
            II=6
            DO 16029 I=1,1024
                 VECT(I,IAXIS)=RARRAY(II+I)
16029 CONTINUE
            IF(NAXIS.LT.3)GO TO 12000
C
C*************************************************************************************)
C
C **** AVERAGING BY INT...
C
20000 NAXIS=0
21000 JVMJD=IVMJD
            DO 24999 IG=1,IGN
                 JVMSOD=IVMSOD+(IG-1)*(RGN*RVDELT)
                 IF(JVMSOD.LT.86400000)GO TO 21200
                 JVMJD=IVMJD+1
                 JVMSOD=JVMSOD-86400000
C
C*************************************************************************************)
C
C **** MIN, MAX, AVERAGE VECTORS OF EACH 16 SAMPLES
C
21200       DO 21209 J=1,3
                 RVSTAT(1,J)=+1.0E+15
                 RVSTAT(2,J)=-1.0E+15
                 RVSTAT(3,J)=0.0
                 NV(J)=0
21209       CONTINUE
            IVT=(IG-1)*INT(RGN)
            I=0
21269       I=I+1
            IV=IVT+I
            DO 21268 J=1,3
                 IF(VECT(IV,J).EQ.99999.0)GO TO 21268
                 IF(VECT(IV,J).LT.RVSTAT(1,J))RVSTAT(1,J)=VECT(IV,J)
                 IF(VECT(IV,J).GT.RVSTAT(2,J))RVSTAT(2,J)=VECT(IV,J)
                 RVSTAT(3,J)=RVSTAT(3,J)+VECT(IV,J)
                 NV(J)=NV(J)+1
21268       CONTINUE
            IF (I.LT.INT(RGN)) GO TO 21269
            DO 21289 J=1,3
                 IF(NV(J).EQ.0)GO TO 21282
```

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```
                      RVSTAT(3,J)=RVSTAT(3,J)/NV(J)
                      GO TO 21289
       21282          RVSTAT(1,J)=0.0
                      RVSTAT(2,J)=99999.0
                      RVSTAT(3,J)=99999.0
                      NV(J)=16
       21289      CONTINUE
       C
       C@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@)
       C
       C **** DISK WRITE VECTOR DATE AND TIME FILTER
       C
       22000      IF(JVMJD.LT.IBMJD)GO TO 24999
                  IF(JVMJD.GT.IEMJD)GO TO 90000
                  IF(JVMJD.NE.IBMJD)GO TO 22030
                  IF(JVMSOD.LT.IBMSOD)GO TO 24999
       22030      IF(JVMJD.LT.IEMJD)GO TO 22200
                  IF(JVMSOD.GT.IEMSOD)GO TO 90000
       C
       C **** SOMETIMES THE FIRST OBSERVATION TIME IS NEGATIVE!
       C
       22200      IF(JVMSOD.LT.0) JVMSOD=JVMSOD+86400000
       C
       C **** WRITE MAGNETIC DATA ONTO DISK
       C
       C **** CHECK FOR MISSING RECORD(S) - HIGH SPEED PLOTTING REQUIRES
       C **** THAT THERE BE NO GAPS IN THE DATA, SO FILL IN THE BLANKS!
       C
       22431      IF ((JVMSOD-JVMSD2).LT.0) GO TO 22432
                  IF ((JVMSOD-JVMSD2).GT.(RVDELT*RGN+983.))
              1   GO TO 24900
                  GO TO 22433
       22432      IF ((JVMSD2-JVMSOD).LT.82800000) GO TO 24999
                  IF ((JVMSOD-JVMSD2+86400000.).GT.(RVDELT*RGN+983.))
              1   GO TO 24900
       C
       C **** WRITE REAL DATA TO DISK
       C
       22433      NMEAS=NMEAS+1
                  NM=NMEAS+IORB
                  WRITE(4'NM) NMEAS,JVMSOD,(RVSTAT(3,J),J=1,3)
                  GO TO 24920
       C
       C **** WRITE DUMMY DATA TO DISK
       C
       24900      NMEAS=NMEAS+1
                  NM=NMEAS+IORB
                  JVMSD2=JVMSD2+RVDELT*RGN
                  IF (JVMSD2.GE.86400000) JVMSD2=JVMSD2-86400000
                  IF ((JVMSOD-JVMSD2).LT.0) GO TO 24901
                  IF ((JVMSOD-JVMSD2).LE.(RVDELT*RGN))
              1   GO TO 24910
                  GO TO 24902
       24901      IF ((JVMSOD-JVMSD2+86400000).LE.(RVDELT*RGN))
              1   GO TO 24910
       24902      RVSTAT(3,1)=99999.
```

```
                 RVSTAT(3,2)=99999.
                 RVSTAT(3,3)=99999.
                 WRITE(4'NM) NMEAS,JVMSD2,(RVSTAT(3,J),J=1,3)
                 GO TO 24900
      24910      NMEAS=NMEAS-1
                 NM=NM-1
      24920      JVMSD2=JVMSOD
      24999 CONTINUE
      C
      C*******************************************************************************)
      C
            GO TO 12000
      C
      90000 TYPE 00101
            ACCEPT 00011, NRWN
            IF (NRWN.GT.1) GO TO 90010
            CALL REWIN(IU,IS)
      90010 WRITE(4'1)NO,NMEAS,KK,NM,IORB
            CLOSE(UNIT=4)
            IF (NRWN.GT.1) GO TO 11111
      99990 STOP
      C<><><><><><><><><><><><>< FORMAT STATEMENTS ><><><><><><><><><><>D
      00001 FORMAT(40A1)
      00011 FORMAT(I)
      00100 FORMAT(  '0MAGSAT DISK')
      00101 FORMAT(  '0ENTER 1 TO REWIND, 2 TO CONTINUE')
      00120 FORMAT(  ' ENTER ''AL'' FOR ALL RECORD LISTING',/,
           *7X,'''OR'' FOR ORBIT RECORD ONLY LISTING.')
      00130 FORMAT ( ' ENTER 1 FOR HEXADECUPLE DENSITY; RETURN FOR REGULAR ' )
      00200 FORMAT (I)
      06903 FORMAT ( ' UNIDENTIFIED RECORD TYPE: ',I4)
      C
            END
```

```
         C<><><><><><><><><><><><><><><><><><><><><><><><><><><><><><><><><><><><>D
         C     RACTW - 1980 APR 18 R.W.COOK
         C           PROGRAM REQUESTS AND CONVERTS TIME WINDOW.                 D
         C
         C<><><><><><><><><><><><><><><><><><><><><><><><><><><><><><><><><><><><>D
         C
0001           SUBROUTINE RACTW
         C
0002           LOGICAL*1 AINS(1)
0003           INTEGER*4 IBDOC,IBMJD,IBHOD,IBSOD,IEDOC,IEMJD,IEHOD,IESOD
0004           REAL*4 BINS(1)
         C
0005           COMMON /MON/MOSEQ,AINS
0006           COMMON /SDTG/IBYOC,IBMOY,IBDOM,IBDOW,IBDOY,IBDOC,IBMJD,
              1              IBHOD,IBMOH,IBSOM,IBSOD,
              2              IEYOC,IEMOY,IEDOM,IEDOW,IEDOY,IEDOC,IEMJD,
              3              IEHOD,IEMOH,IESOM,IESOD
         C                                                                    D
0007           EQUIVALENCE (AINS(1),BINS(1))
         CCCCC
0008     10000 ICCEN=19
0009           GO TO 10100
         C
0010     10011 ACCEPT 00001,(AINS(I),I=1,13)
0011           IF(BINS(1).EQ.'EXIT')GO TO 90000
0012           GO TO (10101,10201),MOSEQ
         C
0013     10100 MOSEQ=1
0014           TYPE 00100
0015           GO TO 10011
0016     10101 DECODE(13,00002,AINS,ERR=10100)IYOC,IMOY,IDOM,IBHOD,IBMOH,IBSOM
0017           CALL YMDDOC(IYOC,IMOY,IDOM,IDOY,IDOC,IDOW)
0018           IBYOC=IYOC
0019           IBMOY=IMOY
0020           IBDOM=IDOM
0021           IBDOY=IDOY
0022           IBDOC=IDOC
0023           IBDOW=IDOW
0024           IBMJD=IBDOC+15020
0025           IBSOD=IBHOD*3600+IBMOH*60+IBSOM
0026           TYPE 00109,IBDOY,IBMJD,IBSOD
0027     10200 MOSEQ=2
0028           TYPE 00200
0029           GO TO 10011
0030     10201 DECODE(13,00002,AINS,ERR=10200)IYOC,IMOY,IDOM,IEHOD,IEMOH,IESOM
0031           CALL YMDDOC(IYOC,IMOY,IDOM,IDOY,IDOC,IDOW)
0032           IEYOC=IYOC
0033           IEMOY=IMOY
0034           IEDOM=IDOM
0035           IEDOY=IDOY
0036           IEDOC=IDOC
0037           IEDOW=IDOW
0038           IEMJD=IEDOC+15020
0039           IESOD=IEHOD*3600+IEMOH*60+IESOM
0040           TYPE 00209,IEDOY,IEMJD,IESOD
         C
```

```
0041      90000 RETURN
          C
          C<><><><><><><><><><><><><><><><><>FORMAT STATEMENTS<><><><><><><><><><><><><><>D
0042      00001 FORMAT(13A1)
0043      00002 FORMAT(3I2,1X,3I2)
0044      00100 FORMAT(' ENTER START DATE AND TIME: YYMMDD HHMMSS')
0045      00109 FORMAT(' BDOY ',I3,', BMJD ',I5,', BSOD ',I8)
0046      00200 FORMAT(' ENTER STOP DATE AND TIME: YYMMDD HHMMSS')
0047      00209 FORMAT(' EDOY ',I3,', EMJD ',I5,', ESOD ',I8)
          C<><><><><><><><><><><><><><><><><><><><><><><><><><><><><><><><><><>D
0048            END
```

```
            SUBROUTINE MTSTAT(ILUN,IS)
      C
      90000 AFOR='0'
            IF(IS.EQ.0)GO TO 99000
      91000 WRITE(06,09000)AFOR,ILUN,IS
            AFOR='+'
            GO TO (91010,91020,91030,91040,91050,91060,91070,91080,91090,
           A91100,91110,91120),IS
      91010 WRITE(06,09010)AFOR
            NF=0
            NR=-1
            CALL SKIPF(ILUN,NF,NR,IS)
            GO TO 90000
      91020 WRITE(06,09020)AFOR
            GO TO 99000
      91030 WRITE(06,09030)AFOR
            GO TO 99000
      91040 WRITE(06,09040)AFOR
            CALL REWIN(ILUN,IS)
            GO TO 99000
      91050 WRITE(06,09050)AFOR
            GO TO 99000
      91060 WRITE(06,09060)AFOR
            GO TO 99000
      91070 WRITE(06,09070)AFOR
            GO TO 99000
      91080 WRITE(06,09080)AFOR
            GO TO 99000
      91090 WRITE(06,09090)AFOR
            GO TO 99000
      91100 WRITE(06,09100)AFOR
            GO TO 99000
      91110 WRITE(06,09110)AFOR
            GO TO 99000
      91120 WRITE(06,09120)AFOR
      99000 RETURN
      C
      09000 FORMAT(A1,'DEVICE ',I2,' STATUS INDICATOR ',I2)
      09010 FORMAT(A1,32X,'PARITY ERROR')
      09020 FORMAT(A1,32X,'EOF')
      09030 FORMAT(A1,32X,'RECORD EXCEEDS REQUESTED LENGTH')
      09040 FORMAT(A1,32X,'EOD')
      09050 FORMAT(A1,32X,'LOAD POINT')
      09060 FORMAT(A1,32X,'EOT')
      09070 FORMAT(A1,32X,'WRITE ATTEMPTED WITHOUT RING')
      09080 FORMAT(A1,32X,'ERROR: ODD BYTE TRANSFER')
      09090 FORMAT(A1,32X,'TAPE SELECT ERROR')
      09100 FORMAT(A1,32X,'ERROR: INVALID PARAMETER')
      09110 FORMAT(A1,32X,'ERROR: UNDOCUMENTED')
      09120 FORMAT(A1,32X,'ERROR: RECORD > 32000 BYTES')
      C
            END
```

```
                SUBROUTINE SBFIBM(BA0,BA1,NB)
        C
        C      SWITCH BYTES FROM IBM DATA INPUT
        C           NB:       THE NUMBER OF BYTES TO BE SWITCHED
        C           INPUT AND OUTPUT ARRAYS CAN BE THE SAME ARRAY
        C
                LOGICAL*1 BA0(1),BA1(1),B
        C
                DO 00099 I=1,NB-1,2
                B=BA0(I)
                BA1(I)=BA0(I+1)
                BA1(I+1)=B
        00099   CONTINUE
                RETURN
                END
```

```
0001              SUBROUTINE SHFIBM(HA0,HA1,NH)
            C
            C     SWITCH HALFWORDS FROM IBM INPUT
            C         NH:        NUMBER OF HALFWORDS INPUT
            C
0002              INTEGER*2 HA0(1),HA1(1),H
            C
0003              DO 00109 I=1,NH-1,2
0004              H=HA0(I)
0005              HA1(I)=HA0(I+1)
0006              HA1(I+1)=H
0007        00109 CONTINUE
0008              RETURN
            C
0009              END
```

```
C*********************************************************************)
C
C  **** ORBPLT PLOTS DATA IN SATORB.DAT
C
C*********************************************************************)
C
        COMMON /ORBIT/ XX,YY,ZZ,SLAT,SLONG,SALT,IDAY,RHEM
        DIMENSION POS(3), CO(3)
        LOGICAL*1 TEXT(6), ATEX(4), DARRAY(14), FNUM(2)
        REAL*4 ILAT, MLT
        INTEGER*2 IMDS(12),IPDM(12)
        INTEGER*4 FIMJD, IBYMD, IBMJD, IBDOC, IBHMS, IBMSOD
        INTEGER*4 LAMJD, IEYMD, IEMJD, IEDOC, IEHMS, IEMSOD
        INTEGER*4 IDOC, NO, NMEAS, IUM, NM, IDUM
        INTEGER*4 NUPO, IMDY
        COMMON IMDS,IPDM
        DATA IMDS/000,031,059,090,120,151,181,212,243,273,304,334/
        DATA IPDM/031,028,031,030,031,030,031,031,030,031,030,031/
        DATA DARRAY / 'S','A','T','O','R','B','.','D','A','T',
     1  ' ',' ',' ',0 /
        DATA PI / 3.14159265 /
        DATA ONE / 1.0 /
C
C*********************************************************************)
C
        WRITE (6,998)
998     FORMAT ( ' ENTER FILE NUMBER:NN ')
        READ (6,999) FNUM
999     FORMAT (2A)
C
        DARRAY(11)=';'
        DARRAY(12)=FNUM(1)
        DARRAY(13)=FNUM(2)
        DARRAY(14)=0
C
        OPEN(UNIT=2,NAME=DARRAY,TYPE='OLD',
     1FORM='UNFORMATTED',ACCESS='DIRECT',RECORDSIZE=5)
        READ (2'1) NO, NMEAS, IUM, NM, IDUM
        READ (2'2) RBYMD, IBDOC, IBMJD, IBHMS, IBMSOD
        READ (2'3) REYMD, IEDOC, IEMJD, IEHMS, IEMSOD
        READ (2'4) RDREFT, SIDTM, DUM1, DUM2, DUM3
        READ (2'5) RHMS, RTOS, CO
C
        RBHMS = RHMS
        CALL TIME (RMSOD, RHMS, RTOS)
        TS = RMSOD
        N = 4 + 2*NO
        READ (2'N) RHMS, RTOS, CO
        REHMS = RHMS
        NOM2 = 2*NO - 7
C
C:::::::::::::::::::::::::::::::::::::::::::::::::::::::::::::::::::::)
C
C  **** REQUEST AND ACCEPT USER SELECTED PARAMETERS
C
11111   CONTINUE
```

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```
                IDAY = 0
        C
                WRITE (6,01000) RBYMD, RBHMS, IBMJD, REYMD, REHMS, IEMJD
        01000   FORMAT ( ' THIS DATA FILE CONTAINS MAGSAT ORBIT DATA '/
             1  '             YYMMDD     HHMMSS.T       MJD '/
             2  ' FROM      ',F7.0,2X,F8.1,4X,I5/
             3  ' TO        ',F7.0,2X,F8.1,4X,I5)
        C
                WRITE (6,01001)
        01001   FORMAT ( ' ENTER 1 TO EXIT; RETURN TO CONTINUE ' )
                READ (6,01002) IEX
        01002   FORMAT (I)
        C
                IF (IEX.EQ.1) GO TO 20909
        C
                WRITE (6,02000)
        02000   FORMAT ( ' ENTER 1 FOR NORTHERN HEMISPHERE,'/
             1  '       2 FOR SOUTHERN HEMISPHERE')
                READ (6,02001) IHEM
        02001   FORMAT (I)
        C
                IF (IHEM.EQ.0) IHEM = 1
                RHEM = IHEM
                IF (IHEM .GT. 1) RHEM = -1.
        C
                WRITE (6,02010)
        02010   FORMAT ( ' ENTER PLOT START DATE:YYMMDD ' )
                READ (6,02030) IYOC,IMOY,IDOM
                CALL YMDDOC (IYOC,IMOY,IDOM,IDOY,IDOC,IDOW)
                FIMJD=IDOC+15020
                IF (IYOC.EQ.0) FIMJD=IBMJD
        C
                WRITE (6,02011)
        02011   FORMAT ( ' ENTER PLOT START TIME:HHMMSS ' )
                READ (6,02029) RSHMS
        C
                IF (RSHMS.EQ.0.) RSHMS = RBHMS
                RTOS = 0.
                IDAY = FIMJD - IBMJD
                CALL TIME (TB, RSHMS, RTOS)
                TB = TB + (FIMJD-IBMJD)*86400000.
                IF (RSHMS.EQ.RBHMS) TB = TB + 60000.
        C
                WRITE (6,02020)
        02020   FORMAT ( ' ENTER PLOT END DATE:YYMMDD ' )
                READ (6,02030) IYOC,IMOY,IDOM
                CALL YMDDOC (IYOC,IMOY,IDOM,IDOY,IDOC,IDOW)
                LAMJD=IDOC+15020
                IF (IYOC.EQ.0) LAMJD=IEMJD
        C
                WRITE (6,02021)
        02021   FORMAT ( ' ENTER PLOT END TIME:HHMMSS ' )
                READ (6,02029) RNHMS
        02029   FORMAT (F7.0)
        02030   FORMAT (3I2)
        C
```

```
            IF (RNHMS.EQ.0.) RNHMS = REHMS
            CALL TIME (TE, RNHMS, RTOS)
            TE = TE + (LAMJD-IBMJD)*86400000.
            IF (RNHMS.EQ.REHMS) TE = TE - 120000.
      C
            DLT = 20000.
            NUPO = INT((TE-TB)/DLT+1)
      C
            I = 0
            I3 = 5
            I4 = I3
            IPL = 0
            IPM = 0
            PAGE = 0.
      C
      C******************************************************************)
      C
      C **** INDICATE USER SELECTED PARAMETERS
      C
      05000 X = 0.
            Y = 0.
            PAGE = PAGE + 1
            IF (I3FL.GT.12) CALL PAUS
            IF (I3FL.GT.12) CALL CALCMP(X,Y,1000,2)
            CALL CALCMP (X,Y,2,3)
            CALL CALCMP (X,Y,0,2)
            CALL CALCMP (0.,0.,0,3)
      C
            DO 10000 N = 1,2
               IF (N.EQ.2) GO TO 10010
               IDOC=FIMJD-15020
               CALL DOCYMD (IDOC,IYOC,IMOY,IDOM,IDOY,IDOW)
               RYMD=IYOC*10000.+IMOY*100.+IDOM
               RMJD=FIMJD
               RHMS = RSHMS
               GO TO 10020
      10010    IDOC=LAMJD-15020
               CALL DOCYMD (IDOC,IYOC,IMOY,IDOM,IDOY,IDOW)
               RYMD=IYOC*10000.+IMOY*100.+IDOM
               RMJD=LAMJD
               RHMS = RNHMS
      10020    HX = 2. + (N-1)*3.5
               CALL SYMBOL (HX,.2,.14,6HYYMMDD,0.,6)
               CALL NUMBER (HX,0.,.14,RYMD,0.,-1)
               HX = HX + 1.
               CALL SYMBOL (HX,.2,.14,5H  MJD,0.,5)
               HX = HX + .14
               CALL NUMBER (HX,0.,.14,RMJD,0.,-1)
               HX = HX + .06
               CALL SYMBOL (HX,.2,.14,6HHHMMSS,0.,6)
               IF (RHMS.LT.100000.) HX = HX + .14
               IF (RHMS.LT.10000.) HX = HX + .14
               IF (RHMS.LT.1000.) HX = HX + .14
               IF (RHMS.LT.100.) HX = HX + .14
               IF (RHMS.LT.10.) HX = HX + .14
               CALL NUMBER (HX,0.,.14,RHMS,0.,-1)
```

```
      10000 CONTINUE
C
            IF (IHEM .GT. 1) GO TO 05010
            CALL SYMBOL (0.,0.7,.20,19HNORTHERN HEMISPHERE,0.,19)
            GO TO 05011
      05010 CALL SYMBOL (0.,0.7,.20,19HSOUTHERN HEMISPHERE,0.,19)
      05011 CALL SYMBOL (0.,0.4,.14,8HORBIT IV,0.,8)
            CALL SYMBOL (0.,0.2,.14,11HGEOMAGNETIC,0.,11)
            CALL SYMBOL (0.,0.0,.14,11HCOORDINATES,0.,11)
            CALL SYMBOL (2.,0.4,.14,4HFROM,0.,4)
            CALL SYMBOL (6.5,0.4,.14,2HTO,0.,2)
            CALL IDATE (IMOY,IDOM,IYOC)
            CALL SYMBOL (12.0,0.2,.14,9HPLOT DATE,0.,9)
            ENCODE (2,01100,TEXT) IMOY
            CALL SYMBOL (12.01,0.0,.14,TEXT,0.,2)
            ENCODE (2,01100,TEXT) IDOM
            CALL SYMBOL (999.,999.,.14,TEXT,0.,2)
            ENCODE (2,01100,TEXT) IYOC
            CALL SYMBOL (999.,999.,.14,TEXT,0.,2)
C
            IF (I3FL.GT.12) CALL SYMBOL (9.,0.,.14,5HPAGE ,0.,5)
            IF (I3FL.GT.12) CALL NUMBER (999.,999.,.14,PAGE,0.,-1)
            I3FL = 0
            IF (I.GT.0) GO TO 20040
C
C**************************************************************)
C
C **** PLOT DATA
C
            I = 0
            TM = TR - TS
      20000 I = I + 1
            TM = TM + DLT
            TCHK = TM + TS - IDAY*86400000.
            IF (TCHK .LT. 86400000.) GO TO 20001
            IDAY = IDAY + 1
      20001 I4 = I3
            IF ((I.EQ.NUPO).AND.(IPM.NE.0)) GO TO 20070
            IF ((I.EQ.NUPO).AND.(IPM.EQ.0)) GO TO 20900
            CALL POSIT (I3,TM,IBMJD,ROREPT,SIDTM,TS,NOM2)
            IF (I4-I3) 20010,20020,20030
C
      20010 GO TO 20070
      20020 IF (I3 .EQ. 4) IPL = 0
            IF (I3-8) 20000,20000,20000
      20030 IPL = 1
C
      20040 I3FL = I3FL + 1
            IF (I3FL .LE. 12) GO TO 20041
            CALL CALCMP (0.,0.,0,3)
            IF (PAGE.EQ.1.) CALL SYMBOL (9.,0.,.14,5HPAGE ,0.,5)
            IF (PAGE.EQ.1.) CALL NUMBER (999.,999.,.14,PAGE,0.,-1)
            GO TO 05000
      20041 XORG = (I3FL-1-4*((I3FL-1)/4))*3.5 + 1.75
            YORG = 9.5-INT((I3FL-1)/4.)*3.17
            CALL CALCMP (XORG,YORG,0,3)
```

```
C
20050   X = 2.*YY/6371.
        IF (IHEM .EQ. 2) X = -X
        Y = -2.*XX/6371.
        IF(SQRT(X**2+Y**2).GT.2.*SIN(40.*PI/180.)) IPL = 1
        IF ((IPM.GT.0).AND.(IPL.EQ.1)) TME=TM+TS-IDAY*86400000.
        IF ((IPL.EQ.0).AND.(I.EQ.(NUPD-1))) TME=TM+TS-IDAY*86400000.
        IF (IPL .EQ. 1) GO TO 20060
        IPM = IPM + 1
        IF (IPM .EQ. 1) TMB = TM + TS - IDAY*86400000.
        CALL CALCMP (X,Y,1,1)
        GO TO 20000
C
20060   IPM = 0
        CALL CALCMP (X,Y,0,1)
        GO TO 20000
C
C **** DRAW LATITUDE CIRCLES
C
20070   DO 21000 K = 10,40,10
          DO 21000 J = 1,101
            X = 2.*SIN(K*PI/180.)*SIN(J*PI/50.)
            Y = -2.*SIN(K*PI/180.)*COS(J*PI/50.)
            IF (J .EQ. 1) CALL CALCMP(X,Y,0,1)
            CALL CALCMP(X,Y,1,1)
21000   CONTINUE
C
C **** INDICATE ORBIT PLOT START AND STOP TIME
C
        DAY = IBMJD + IDAY
        CALL NUMBER (.95,1.13,.14,DAY,0.,-1)
        XTIM = -1.5
        YTIM = -1.5
        CALL HOMISE (TEXT,TMB)
        CALL SYMBOL (XTIM,YTIM,.14,TEXT,0.,6)
        XTIM = .7
        YTIM = -1.5
        CALL HOMISE (TEXT,TME)
        CALL SYMBOL (XTIM,YTIM,.14,TEXT,0.,6)
C
C **** DRAW MLT LINES AND INDICATE MLT
C
        DO 22000 K = 1,4
          S = SIN((K-1)*PI/2.)
          C = COS((K-1)*PI/2.)
          X = 2.*S*SIN(10.*PI/180.)
          Y = -2.*C*SIN(10.*PI/180.)
          CALL CALCMP(X,Y,0,1)
          X = 2.*S*SIN(40.*PI/180.)
          Y = -2.*C*SIN(40.*PI/180.)
          CALL CALCMP(X,Y,1,1)
          RNUM = (K-1)*6.
          GO TO (22010,22020,22030,22040) K
22010     XL = -.04
          YL = -1.5
          GO TO 22100
```

```
22020       XL = 1.37
            YL = -.07
            IF (IHEM .EQ. 2) RNUM = 18.
            GO TO 22100
22030       XL = -.11
            YL = 1.36
            GO TO 22100
22040       XL = -1.57
            YL = -.07
            IF (IHEM .EQ. 2) RNUM = 6.
22100     CALL NUMBER (XL,YL,.14,RNUM,0.,-1)
22000   CONTINUE
      IF (I.LT.NUPO) GO TO 20000
C
01100 FORMAT (I2)
C
C************************************************************)
C
20400 CALL PAUS
      CALL CALCMP(X,Y,1000,2)
      WRITE (6,02100)
02100 FORMAT ( ' TYPE 1 TO STOP; RETURN TO CONTINUE' )
      READ (6,02101) N
02101 FORMAT (I)
      IF (N .NE. 1) GO TO 11111
20969 CLOSE (UNIT=2)
      STOP
      END
```

```
C
C*****************************************************************)
C
      SUBROUTINE HOMISE (TEXT,TM)
      LOGICAL*1 TEXT(6)
      INTEGER*4 IHMS
      RH = AINT(TM/3600000.)
      RM = AINT((TM - RH*3600000.)/60000.)
      RS = AINT((TM - RH*3600000. - 60000.*RM)/1000.)
      IHMS = JINT(10000.*RH + 100.*RM + RS)
      ENCODE (6,01000,TEXT) IHMS
01000 FORMAT (I6)
      RETURN
      END
```

```
C*************************************************************************)
C
C **** MSPLT PLOTS DATA IN MAGSAT.DAT
C
C*************************************************************************)
C
      DIMENSION POS(3),CO(3),V(4),B(4),FMAX(4)
      DIMENSION XPL(50),YPL(4,50),FLD(4),BSDV(4)
      DIMENSION YPTEM(4)
      LOGICAL*1 TEXT(6),ATEX(8),DARRAY(14),FNUM(2)
      LOGICAL*1 MGST(12)
      INTEGER*2 IMDS(12),IDPM(12)
      INTEGER*4 FIMJD,IBMJD,IBDOC,IBHMS,IBMSOD
      INTEGER*4 LAMJD,IEMJD,IEDOC,IEHMS,IEMSOD
      INTEGER*4 NO,NMEAS,JDUM,NM,IORB,IDOC
      INTEGER*4 N,NFR,NLR,NUPO,IDAT,IPLOT
      INTEGER*4 JMSD,JMSD2,JT1,JTL,JTR,JTE,JTB
      REAL*8 TB,TE,TM,TS,TCHK,DLT
      REAL*4 ILAT,MLT,LHMS
      COMMON IMDS,IDPM
      COMMON /ORBIT/ XX,YY,ZZ,SLAT,SLONG,SALT,IDAY
      DATA IMDS/000,031,059,090,120,151,181,212,243,273,304,334/
      DATA IDPM/031,028,031,030,031,030,031,031,030,031,030,031/
      DATA ATEX / 'S','D','C','F','N','E','C','F' /
      DATA DARRAY / 'M','A','G','S','A','T','.','D','A','T',
     1 '.',';','1','0' /
      DATA MGST / 'M','G','S','T','6','8','8','.','D','A','T',0 /
      DATA PI / 3.14159265 /
C
C*************************************************************************)
C
C **** DATA ENTRY SECTION
C
      WRITE (6,998)
998   FORMAT ( ' ENTER FILE NUMBER:NN ' )
      READ (6,999) FNUM
999   FORMAT (2A)
      DARRAY(12)=FNUM(1)
      DARRAY(13)=FNUM(2)
C
      OPEN(UNIT=2,NAME=DARRAY,TYPE='OLD',
     1FORM='UNFORMATTED',ACCESS='DIRECT',RECORDSIZE=8)
      READ (2'1) NO,NMEAS,JDUM,NM,IORB
      READ (2'2) RBYMD,IBDOC,IBMJD,IBHMS,IBMSOD
      READ (2'3) REYMD,IEDOC,IEMJD,IEHMS,IEMSOD
      READ (2'4) ROREFT,SIDTM,DUM1,DUM2,DUM3
      READ (2'5) JDUM,JMSD,CO
      TS=JMSD
C
C **** FIND TIME OF FIRST AND LAST MAGNETIC DATA RECORD
C
      N=5+IORB
      READ (2'N) JDUM,JMSD,(V(I),I=1,3)
      CALL TOD (JMSD,FHMS)
      N=NM
      READ (2'N) JDUM,JMSD,(V(I),I=1,3)
```

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```
0040            CALL TOD (JMSD,LHMS)
          C
0041      11111 CONTINUE
0042            OPEN(UNIT=1,NAME=MGST,TYPE='OLD',
               1FORM='FORMATTED')
          C
0043            WRITE (6,01000) RBYMD,FHMS,IBMJD,REYMD,LHMS,IEMJD
0044      01000 FORMAT ( ' THIS DATA FILE CONTAINS MAGSAT DATA '/
              1 '          YYMMDD    HHMMSS.T      MJD '/
              2 ' FROM    ',F7.0,2X,F8.1,4X,I5/
              3 ' TO      ',F7.0,2X,F8.1,4X,I5)
          C
0045            WRITE (6,01102)
0046      01102 FORMAT ( ' ENTER 1 TO EXIT; RETURN TO CONTINUE ')
0047            READ (6,01103) IEX
0048      01103 FORMAT (I)
          C
0049            IF (IEX.EQ.1) GO TO 20909
          C
          C **** DETERMINE MSOD FOR BEGINNING AND ENDING PLOT POINTS
          C
0050            WRITE (6,01100)
0051      01100 FORMAT ( ' ENTER PLOT START MODIFIED JULIAN DAY:DDDDD ' )
0052            READ (6,01109) FIMJD
          C
0053            WRITE (6,01101)
0054      01101 FORMAT ( ' ENTER PLOT START TIME:HHMMSS ' )
0055            READ (6,01108) RSHMS
          C
0056            WRITE (6,01110)
0057      01110 FORMAT ( ' ENTER PLOT END MODIFIED JULIAN DAY:DDDDD ' )
0058            READ (6,01109) LAMJD
          C
0059            WRITE (6,01111)
0060      01111 FORMAT ( ' ENTER PLOT END TIME:HHMMSS ' )
0061            READ (6,01108) RNHMS
0062      01108 FORMAT (F7.0)
0063      01109 FORMAT (I6)
          C
0064            IF (FIMJD.EQ.0.) FIMJD=IBMJD
0065            IF (RSHMS.EQ.0.) RSHMS=FHMS
0066            RTOS=0.
0067            IDAY=FIMJD-IBMJD
0068            IDAY2=IDAY
0069            CALL TIME (TB,RSHMS,RTOS)
0070            TB=TB+IDAY*86400000.
0071            IF (RSHMS.EQ.FHMS) TB=TB+3000.
          C
0072            IF (LAMJD.EQ.0.) LAMJD=IEMJD
0073            IF (RNHMS.EQ.0.) RNHMS=LHMS
0074            CALL TIME (TE,RNHMS,RTOS)
0075            TE=TE+(LAMJD-IBMJD)*86400000.
0076            IF (RNHMS.EQ.LHMS) TE=TE-120000.
          C
0077            WRITE (6,01200)
0078      01200 FORMAT ( ' ENTER 1 FOR SDV; 2 FOR NEV ' )
```

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```
0079            READ (6,01201) ICO
0080      01201 FORMAT (I)
0081            IF (ICO.EQ.0) ICO=1
      C
      C **** DETERMINE TIME BETWEEN DATA POINTS, NUMBER OF POINTS
      C **** IN INTERVAL AND RECORD NUMBERS FOR FIRST AND LAST
      C **** DATA POINTS TO BE PLOTTED
      C
0082            N=5+IORB
0083            READ (2'N) JDUM,JT1,(V(I),I=1,3)
0084            N=NM
0085            READ (2'N) JDUM,JTL,(V(I),I=1,3)
0086            TL=JTL+(IEMJD-IBMJD)*86400000.
0087            DLT=(TL-JT1)/(NMEAS-1.)
0088            NUPO=JIDINT((TE-TB)/DLT)
0089            NFR=4+IORB+JIDINT((TB-JT1)/DLT)
0090            READ (2'NFR) JDUM,JTR,(V(I),I=1,3)
0091            NFR=NFR+JIDINT((TB-JTR-IDAY*86400000.)/DLT)
0092            NLR=4+IORB+JIDINT((TE-JT1)/DLT)
0093            READ (2'NLR) JDUM,JTR,(V(I),I=1,3)
0094            NLR=NLR+JIDINT((TE-JTR-(LAMJD-IBMJD)*86400000.)/DLT)
      C
      C **** DETERMINE NUMBER OF POINTS TO BE PLOTTED,FRACTION TO BE
      C **** SKIPPED, AND AVERAGE TIME BETWEEN PLOT POINTS
      C
0095            WRITE (6,01300) NUPO
0096      01300 FORMAT ( ' THERE ARE ',I6,
          1  ' DATA POINTS WITHIN THE CHOSEN INTERVAL'/
          2  ' ENTER THE NUMBER OF POINTS TO BE PLOTTED.')
0097            READ (6,01301) N
0098      01301 FORMAT (4I)
      C
0099            IF (N.EQ.0) N=NUPO/4
0100            SKP=FLOAT(NLR-NFR+1)/FLOAT(N)
0101            DT=(TE-TB)/N
      C
      C*****************************************************************)
      C
      C **** INTITIALIZE
      C
0102            DO 06000 I=1,4
0103               FMAX(I)=0.
0104               FLD(I)=0.
0105      06000 CONTINUE
0106            BX=0.
0107            BY=0.
0108            BZ=0.
0109            BF=0.
0110            IPO1=0
0111            IPO2=0
0112            NOM2=2*NO-8
0113            IPOS=0
0114            IPL=0
0115            J=1
0116            MM=0
0117            NEXT=1
```

```
      NMX=14
      L=1
      TI=1979.98770
      CALL CALCMP (0.,0.,2,0)
      CALL CALCMP (0.,0.,0,2)
      CALL CALCMP (.93,.93,0,4)
      CALL CALCMP (.2,.2,0,3)
C
C*************************************************************************)
C
C **** DATA PLOTTING SECTION
C
      DO 10000 IPOS=1,3
         JMSD2=0
         IDAY=IDAY2
         IPLOT=0
C
         DO 10000 IDAT=NFR,NLR
            IF ((IPOS.EQ.3).AND.(IDAT.EQ.NFR)) SKP=(NLR-NFR+1)/100.
C
C **** DETERMINE WHETHER TO PLOT OR NOT ACCORDIND TO THE SKIP
C **** FRACTION AND THE NUMBER OF POINTS ALREADY PLOTTED
C
            IF ((FLOAT(IPLOT+1)/FLOAT(IDAT-NFR+1)) .GT.
     1      ((1./SKP)+1./FLOAT(IDAT-NFR+1))) GO TO 10010
            IF ((FLOAT(IPLOT+1)/FLOAT(IDAT-NFR+1)) .LT.
     1      ((1./SKP)-1./FLOAT(IDAT-NFR+1))) GO TO 10010
            GO TO 10020
C
10010       IF (IPOS.NE.2) GO TO 10000
            IF (IDAT.NE.NLR) GO TO 10000
            GO TO 10050
C
C **** DETERMINE SATELLITE POSITION
C
10020       IPLOT=IPLOT+1
            READ (2'IDAT) JDUM,JMSD,(V(JJ),JJ=1,3)
            IF (JMSD.LT.JMSD2) IDAY=IDAY+1
            TM=JMSD-TS+IDAY*86400000.
            JMSD2=JMSD
            CALL POSIT (IPOS,TM,IBMJD,ROREFT,SIDTM,TS,NOM2)
            Q=SALT+6371.
            IF (IPOS.LT.3) GO TO 10030
C
C **** PLOT ORBIT IN GEOMAGNETIC COORDINATES
C
            IF (IPO1.LT.IPO2) CALL CALCMP (X,Y,0,-5)
            IF (IPO1.GT.IPO2) CALL CALCMP (X,Y,0,-5)
            IPO1=IPO2
            X=YY/(6371.*SIN(40.*PI/180.))+12.75
            Y=-XX/(6371.*SIN(40.*PI/180.))+8.4
            IF (IPLOT.EQ.1) CALL CALCMP(X,Y,0,1)
            CALL CALCMP(X,Y,1,1)
            CALL POSIT (IPO1,TM,IBMJD,ROREFT,SIDTM,TS,NOM2)
            IPO2=0
            IF (SLAT.LT.0.) IPO2=1
```

```
                    GO TO 10000
      C
      C **** DETERMINE GEOMAGNETIC COMPONENTS, SUBTRACT FROM MAGSAT
      C **** COMPONENTS, AND FIND MAXIMA
      C
      10030         CALL FDG(J,MM,NEXT,SLAT,SLONG,Q,TI,NMX,L,BX,BY,BZ,BF)
      C
                    IF (IPLOT.EQ.1) TB=TM
                    IF (IPOS.EQ.1) TE=TM
                    B(1)=BX
                    B(2)=BY
                    B(3)=BZ
                    B(4)=BF
                    V(4)=SQRT(V(1)**2+V(2)**2+V(3)**2)
                    DO 11000 I=1,4
                       FLD(I)=V(I)-B(I)
                       IF (V(I).GT.99990.) FLD(I)=0.
                       IF (V(I).GT.99990.) FLD(4)=0.
                       IF((IPOS.GT.1).OR.(ICO.EQ.1)) GO TO 11000
                       FMAX(I)=AMAX1(ABS(FLD(I)),FMAX(I))
      11000         CONTINUE
                    IF (ICO.EQ.2) GO TO 10031
      C
      C **** CONVERT TO SDV IF SELECTED
      C
                    UT=360.*JMSD/86400000.
                    SH=SIN((UT+SLONG-90.)*PI/180.)
                    CH=COS((UT+SLONG-90.)*PI/180.)
                    BSDV(1)=-FLD(1)*SH+FLD(2)*CH
                    BSDV(2)=-FLD(1)*CH-FLD(2)*SH
                    BSDV(3)= FLD(3)
                    BSDV(4)= FLD(4)
                    DO 12000 I=1,4
                       FLD(I)=BSDV(I)
                       IF (IPOS.GT.1) GO TO 12000
                       FMAX(I)=AMAX1(ABS(FLD(I)),FMAX(I))
      12000         CONTINUE
      C
      10031         IF (IPOS.EQ.1) GO TO 17000
                    IF (IDAT.GT.NFR) GO TO 10040
      C
                    FMAX(1)=AMAX1(FMAX(1),FMAX(2))
                    FMAX(2)=FMAX(1)
                    FMAX(3)=AMAX1(FMAX(3),FMAX(4))
                    FMAX(4)=FMAX(3)
      C
      C **** NORMALIZE PLOT TO NEAREST 50NT IF FIELD STRENGTH GREATER
      C **** THAN 50NT, TO NEAREST 10NT IF LESS, AND INDICATE THESE
      C **** PLOT LIMITS
      C
                    DO 13000 I=1,4
                       IF (FMAX(I).LE.50.) GO TO 13010
                       FMAX(I)=50.*INT(FMAX(I)/50.+1)
                       GO TO 13020
      13010            FMAX(I)=10.*INT(FMAX(I)/10.+1)
      13020            XL=1.2
```

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```
                YL=(5-I)*2.4+.8
                M=I+4*(ICO-1)
                CALL SYMBOL (XL,YL,.28,ATEX(M),0.,1)
                XL=.24
                YL=2.4*(5-I)+1.
                CALL NUMBER (XL,YL,.14,FMAX(I),0.,0)
                FM=0.
                XL=.74
                YL=2.4*(5-I) -.09
                CALL NUMBER (XL,YL,.14,FM,0.,0)
                FM=-FMAX(I)
                XL=.1
                YL=2.4*(5-I)-1.15
                CALL NUMBER (XL,YL,.14,FM,0.,0)
 13000       CONTINUE
C
C **** DETRMINE VALUES OF POINTS TO BE PLOTTED AND STORE UP TO
C **** 50 TO PLOT ALL AT ONCE
C
 10040       IPL=IPL+1
             XPL(IPL)=1.+10.*(TM-TB)/(TE-TB)
             DO 14000 I=1,4
                YPL(I,IPL)=2.4*(5-I)+1.2*FLD(I)/FMAX(I)
 14000       CONTINUE
             IF ((IPL.LT.50).AND.(IDAT.NE.NLR)) GO TO 10000
C
C **** PLOT DATA
C
 10050       DO 15000 I=1,4
                IF (IPLOT.LE.50) GO TO 15010
                IF ((IDAT.EQ.NLR).AND.(IPL.EQ.0)) GO TO 15010
                X=XPTEM
                Y=YPTEM(I)
                CALL CALCMP(X,Y,0,1)
                X=XPL(1)
                Y=YPL(I,1)
                CALL CALCMP(X,Y,1,1)
 15010          DO 15000 IPN=1,IPL
                   X=XPL(IPN)
                   Y=YPL(I,IPN)
                   IF (IPN.EQ.1) CALL CALCMP(X,Y,0,1)
                   IF (IPN.EQ.1) GO TO 15000
                   CALL CALCMP(X,Y,1,1)
 15000       CONTINUE
          XPTEM=XPL(IPL)
          DO 16000 I=1,4
             YPTEM(I)=YPL(I,IPL)
 16000    CONTINUE
          IPL=0
 10000 CONTINUE
C
       CALL CALCMP (X,Y,0,-5)
C
C**************************************************************)
C
C **** BACKGROUND SECTION
```

```
      C
            CALL SYMBOL (-.1,0.,.14,4H MLT,0.,4)
            CALL SYMBOL (-.1,.2,.14,4HILAT,0.,4)
            CALL SYMBOL (-.1,.4,.14,4H ALT,0.,4)
            CALL SYMBOL (-.1,.6,.14,4HLONG,0.,4)
            CALL SYMBOL (-.1,.8,.14,4H LAT,0.,4)
            CALL SYMBOL (-.1,1.,.14,4HTIME,0.,4)
            CALL SYMBOL (.02,4.6,.21,11HDELTA-B IN ,90.,11)
            CALL SYMBOL (999.,999.,.21,10HNANOTESLAS,90.,10)
            CALL SYMBOL (11.6,10.5,.42,6HMAGSAT,0.,6)
            CALL SYMBOL (11.62,10.5,.42,6HMAGSAT,0.,6)
      C
      C **** DRAW LATITUDE CIRCLES ...
      C
            DO 20000 I=1,4
                DO 20000 J=1,101
                    X=SIN(I*PI/18.)*SIN(J*PI/50.)/SIN(4.*PI/18.)+12.75
                    Y=-SIN(I*PI/18.)*COS(J*PI/50.)/SIN(4.*PI/18.)+8.4
                    IF (J.EQ.1) CALL CALCMP(X,Y,0,1)
                    CALL CALCMP(X,Y,1,1)
      20000 CONTINUE
      C
      C **** ... AND MLT
      C
            DO 30000 I=1,4
                SH=SIN((I-1)*PI/2.)
                CH=COS((I-1)*PI/2.)
                X=.25*SH+12.75
                Y=-.25*CH+8.4
                CALL CALCMP(X,Y,0,1)
                X=SH+12.75
                Y=-CH+8.4
                CALL CALCMP(X,Y,1,1)
                RNUM=(I-1)*6.
                GO TO (30010,30020,30030,30040) I
      30010     XL=12.72
                YL=7.2
                GO TO 30100
      30020     XL=13.82
                YL=8.33
                GO TO 30100
      30030     XL=12.63
                YL=9.47
                GO TO 30100
      30040     XL=11.45
                YL=8.33
      30100     CALL NUMBER (XL,YL,.14,RNUM,0.,-1)
      30000 CONTINUE
      C
            CALL SYMBOL (12.47,6.95,.14,5HORBIT,0.,5)
            CALL SYMBOL (12.05,6.70,.14,11HGEOMAGNETIC,0.,11)
            CALL SYMBOL (12.05,6.50,.14,11HCOORDINATES,0.,11)
            CALL SYMBOL (11.94,6.9,.10,5HBEGIN,0.,5)
            CALL SYMBOL (11.8,6.6,.14,6HYYMMDD,0.,6)
            IDOC=FIMJD-15029
            CALL DOCYMD (IDOC,IYOC,IMOY,IDOM,IDOY,IDOW)
```

```
              RYMD=IYOC*10000.+IMOY*100.+IDOM
              CALL NUMBER (11.0,5.4,.14,RYMD,0.,-1)
              ENCODE (6,02000,TEXT) FIMJD
              CALL SYMBOL (11.73,5.1,.14,5H  MJD,0.,5)
              CALL SYMBOL (11.73,4.9,.14,TEXT,0.,6)
              CALL SYMBOL (13.32,5.9,.10,3HEND,0.,3)
              CALL SYMBOL (13.05,5.6,.14,6HYYMMDD,0.,6)
              IDOC=LAMJD-15020
              CALL DOCYMD (IDOC,IYOC,IMOY,IDOM,IDOY,IDOW)
              RYMD=IYOC*10000.+IMOY*100.+IDOM
              CALL NUMBER (13.05,5.4,.14,RYMD,0.,-1)
              ENCODE (6,02000,TEXT) LAMJD
              CALL SYMBOL (12.97,5.1,.14,5H  MJD,0.,5)
              CALL SYMBOL (12.97,4.9,.14,TEXT,0.,6)
              CALL SYMBOL (12.0,4.2,.14,11HDELTA-T IN ,0.,11)
              CALL SYMBOL (12.0,4.0,.14,7HMSEC = ,0.,7)
              CALL NUMBER (999.,999.,.14,DT,0.,-1)
              CALL IDATE (IMOY,IDOM,IYOC)
              CALL SYMBOL (12.0,.2,.14,9HPLOT DATE,0.,9)
              ENCODE (2,02010,TEXT) IMOY
              CALL SYMBOL (12.81,0.,.14,TEXT,0.,2)
              ENCODE (2,02010,TEXT) IDOM
              CALL SYMBOL (999.,999.,.14,TEXT,0.,2)
              ENCODE (2,02010,TEXT) IYOC
              CALL SYMBOL (999.,999.,.14,TEXT,0.,2)
        02000 FORMAT (I6)
        02010 FORMAT (I2)
        C
        C **** DRAW TIME TIC-MARKS AND INDICATE ORBITAL STATUS
        C
              READ (2'INPR) JDUM,JTB,(V(I),I=1,3)
              TB=JTB+IDAY*86400000.
              READ (2'INLR) JDUM,JTE,(V(I),I=1,3)
              TE=JTE+(LAMJD-IBMJD)*86400000.
              PDT=(TE-TB)/10.
        C
              DO 40000 I=1,11
                 DO 41000 JJ=1,5
                    X=I
                    Y=2.4*(5-JJ)+1.25
                    CALL CALCMP(X,Y,0,1)
                    X=I
                    Y=2.4*(5-JJ)+1.15
                    CALL CALCMP(X,Y,1,1)
        41000    CONTINUE
                 TM=TB+(I-1)*PDT-TS
                 ICHK=TM+TS-IDAY*86400000.
                 IF (ICHK.GT.86400000.) IDAY=IDAY+1
                 CALL POSIT (IPOS,TM,IBMJD,ROREFT,SIDTM,TS,NOM2)
                 TM=TM+TS-IDAY*86400000.
                 CALL HOMISE (TEXT,TM)
                 XL=I-.29
                 CALL SYMBOL (XL,1.,.14,TEXT,0.,6)
                 CALL NUMBER (XL,.8,.14,SLAT,0.,1)
                 CALL NUMBER (XL,.6,.14,SLONG,0.,1)
                 CALL NUMBER (XL,.4,.14,SALT,0.,1)
```

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```
              IPOS=3
              TM=TB+(I-1)*PDT-TS
              CALL POSIT (IPOS,TM,DUM1,DUM2,DUM3,TS,NOM2)
              SLONG=SLONG/15.
              CALL NUMBER (XL,.2,.14,SLAT,0.,1)
              CALL NUMBER (XL,0.,.14,SLONG,0.,1)
              IPOS=0
40000 CONTINUE
C
C **** DRAW PLOT BOUNDARIES AND MAGNETIC TIC-MARKS
C
      DO 50000 I=1,9
              X=1.
              Y=I*1.2
              CALL CALCMP (X,Y,0,1)
              X=11.
              Y=I*1.2
              CALL CALCMP (X,Y,1,1)
              IF (I .EQ. 9) GO TO 50000
              DO 50000 N=1,18
                 M=N
                 IF (N .GT. 9) M=N-9
                 XL=1.
                 IF (N .GT. 9) XL=10.9
                 X=XL
                 Y=(M/10.+I)*1.2
                 CALL CALCMP (X,Y,0,1)
                 X=.1+XL
                 Y=(M/10.+I)*1.2
                 CALL CALCMP (X,Y,1,1)
50000 CONTINUE
C
C*******************************************************************)
C
      CALL PAUS
      CALL CALCMP(X,Y,1000,2)
      CLOSE (UNIT=1)
      WRITE (6,01400)
01400 FORMAT ( ' TYPE 1 TO STOP; RETURN TO CONTINUE ' )
      READ (6,01401) N
01401 FORMAT (I)
      IF (N.NE.1) GO TO 11111
20909 CLOSE (UNIT=2)
      STOP
      END
```

```
      C
      C*****************************************************************)
      C
            SUBROUTINE HOMISE (TEXT,TM)
            REAL*8 TM
            LOGICAL*1 TEXT(6)
            INTEGER*4 IHMS
            RH=AINT(TM/3600000.)
            RM=AINT((TM-RH*3600000.)/60000.)
            RS=AINT((TM-RH*3600000.-60000.*RM)/1000.)
            IHMS=JINT(10000.*RH+100.*RM+RS)
            ENCODE (6,01000,TEXT) IHMS
      01000 FORMAT (I6)
            RETURN
            END
```

```
0001          SUBROUTINE FDG (J,MM,NEXT,DLAT,DLONG,Q,TM,NMX,L,X,Y,Z,F)
       C***********************************************************************
       C   J.EQ.0     INPUTS LATITUDE & Q=ALTITUDE (KM) RELATIVE TO ELLIPSOID
       C              (GEODETIC COORDINATES)
       C   J.EQ.0     OUTPUT FIELD COMPONENTS NORTH,EAST,VERTICAL
       C              IN GEODETIC COORDINATES
       C
       C   J.NE.0     LAT,&LONG IN SPHERICAL COORDINATES, Q=GEOCENTRIC RADIUS(KM)
       C   J.NE.0     OUTPUT FLD COMPONENTS NORTH,EAST,VERTICAL IN SPHERICAL COOR
       C
       C   MM.EQ.0    USE DEFAULT VALUES AE=6378.16,FLAT=298.25
       C   MM.NE.0    INPUT VALUES FOR AE,FLAT      ON FIRST CALL TO FDG
       C
       C   NEXT.EQ.0 DO NOT READ INPUT VALUES FOR EXTERNAL FIELD PARAMETERS
       C              WHEN L IS GREATER THAN 0
       C   NEXT.EQ.0 DO NOT EVALUATE EXTERNAL FIELD FROM MODEL
       C   NEXT.NE.0 READ INPUT VALUES FOR EXTERNAL FIELD PARAMETERS WHEN
       C              L GREATER 0
       C   NEXT.NE.0 EVALUATE EXTERNAL FIELD MODEL
       C
       C   DLAT       GEODETIC LATITUDE IN DEGREES WHEN J=0
       C              GEOCENTRIC LATITUDE IN DEGREES WHEN J=1
       C
       C   DLONG      LONGITUDE IN DEGREES
       C
       C   Q          GEODETIC ALTITUDE (KM) WHEN J=0
       C              GEOCENTRIC RADIUS (KM) WHEN J=1
       C
       C   NMAX       MAXIMUM DEGREE AND ORDER OF CONSTANT TERMS OF FIELD MODEL
       C   NMAXT      "       "      "   FIRST ORDER TIME   "     "     "     "
       C   NMAXTT     "       "      "   SECOND      "      "     "     "     "
       C   NMXTTT     "       "      "   THIRD       "      "     "     "     "
       C
       C   K.EQ.0     FIELD MODEL COEFFICIENTS SCHMIDT NORMALIZED
       C   K.NE.0     FIELD MODEL COEFFICIENTS GAUSS NORMALIZED
       C
       C   TZERO      EPOCH TIME FOR FIELD MODEL COEFFICIENTS
       C
       C   ABAR       MEAN RADIUS USED IN FIELD MODEL POTENTIAL EXPANSION
       C              (DEFAULT = 6371.2)
       C
       C   MODEXT.EQ.0 NO EXTERNAL FIELD SOLVED WITH MODEL
       C   MODEXT.NE.0 EXTERNAL FIELD SOLVED WITH MODEL
       C   L.EQ.0     EVALUATE FIELD
       C   L.GT.0     READ IN FIELD MODEL AND EVALUATE FIELD
       C   L.LE.0     EVALUATE FIELD AT OLD TIME
       C
       C***********************************************************************
0002          EQUIVALENCE (SHMIT(1,1),TG(1,1))
0003          COMMON /COEFFS/TG(18,18)
0004          COMMON /FLDCOM/ST,CT,SPH,CPH,R,NMAX,BT,BP,BR,B,
             &ABAR,E1,E2,E3,NEXTF
0005          DIMENSION G(18,18),GT(18,18),SHMIT(18,18),AID(30)
0006          DIMENSION GTTT(8,8),GTT(18,18)
0007          DATA IFRST/0/
0008          DATA AE,FLAT/6378.16,298.25/
```

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```
      DATA TLAST/0./
      DATA TABAR/6371.2/
      IF(IFRST) 110,100,110
  100 CONTINUE
      IFRST=1
      FLAT=1. -1./FLAT
      E1=0.
      E2=0.
      E3=0.
      A2=AE**2
      A4=AE**4
      B2=(AE*FLAT)**2
      A2B2=A2*(1.-FLAT**2)
      A4B4=A4*(1.-FLAT**4)
  110 IF (L) 19,1,2
1     IF (TM-TLAST) 17,19,17
2     READ (1,3) NMAX,NMAXT,NMAXTT,NMXTTT,MODEXT,K,TZERO,ABAR,
     &(AID(I),I=1,10)
3     FORMAT(4I2,2I2,2F6.1,9A6,A2)
      IF(ABAR.EQ.0.) ABAP=TABAR
      READ(1,103) (AID(I),I=11,30)
103   FORMAT(20A4)
      L=0
      MAXN=0
      TEMP=0.
5     READ (1,6) N,M,GNM,HNM,GTNM,HTNM,GTTNM,HTTNM
6     FORMAT (2I3,6F11.4)
      IF (N.LE.0) GOTO7
      MAXN=(MAX0(N,MAXN))
      G(N,M)=GNM
      GT(N,M)=GTNM
      GTT(N,M)=GTTNM
      TEMP=AMAX1(TEMP,ABS(GTNM))
      IF (M.EQ.1) GOTO5
      G(M-1,N)=HNM
      GT(M-1,N)=HTNM
      GTT(M-1,N)=HTTNM
      GO TO 5
7     IF(NMXTTT.EQ.0) GO TO 107
106   READ(1,6)N,M,GTTTNM,HTTTNM
      IF(N.EQ.0) GO TO 107
      IF(N.GT.8) STOP 106
      GTTT(N,M)=GTTTNM
      IF(M.EQ.1) GO TO 106
      GTTT(M-1,N)=HTTTNM
      GO TO 106
107   CONTINUE
      IF(NEXT.NE.0) FEAD(1,102) E1,E2,EG
102   FORMAT(6X,3F9.2)
      DO 12 N=2,MAXN
      DO 12 M=1,N
      MI=M-1
      IF (M.EQ.1) GOTO10
      GO TO 12
10    CONTINUE
12    CONTINUE
```

```
13    FORMAT (1H1)
      IF (TEMP.EQ.0.) L=-1
14    IF (K.NE.0) GOTO17
      SHMIT(1,1)=-1.
      DO 15 N=2,MAXN
      SHMIT(N,1)=SHMIT(N-1,1)*FLOAT(2*N-3)/FLOAT(N-1)
      SHMIT(1,N)=0.
      JJ=2
      DO 15 M=2,N
      SHMIT(N,M)=SHMIT(N,M-1)*SQRT(FLOAT((N-M+1)*JJ)/FLOAT(N+M-2))
      SHMIT(M-1,N)=SHMIT(N,M)
15    JJ=1
      DO 16 N=2,MAXN
      DO 16 M=1,N
      G(N,M)=G(N,M)*SHMIT(N,M)
      GT(N,M)=GT(N,M)*SHMIT(N,M)
      IF(NMXTTT.GT.0.AND.N.LE.8)GTTT(N,M)=GTTT(N,M)*SHMIT(N,M)
      IF (M.EQ.1) GOTO16
      G(M-1,N)=G(M-1,N)*SHMIT(M-1,N)
      GT(M-1,N)=GT(M-1,N)*SHMIT(M-1,N)
      IF(NMXTTT.GT.0.AND.N.LE.8)GTTT(M-1,N)=GTTT(M-1,N)*SHMIT(M-1,N)
16    CONTINUE
17    T=TM-TZERO
      DO 18 N=1,MAXN
      DO 18 M=1,N
      TGX=0.
      THX=0.
      IF(M.EQ.1) GO TO 270
      IF(N.GT.NMXTTT) GO TO 210
      TGX=GTTT(N,M)*T
      THX=GTTT(M-1,N)*T
210   IF(N.GT.NMAXTT) GO TO 220
      TGX=(TGX + GTT(N,M))*T
      THX= (THX + GTT(M-1,N))*T
220   IF(N.GT.NMAXT) GO TO 230
      TGX=(TGX + GT(N,M))*T
      THX=(THX+GT(M-1,N))*T
230   TGX=TGX+G(N,M)
      THX=THX+G(M-1,N)
      TG(N,M)=TGX
      TG(M-1,N)=THX
      GO TO 18
 270  CONTINUE
      IF(N.GT.NMXTTT) GO TO 240
      TGX=GTTT(N,M)*T
240   IF(N.GT.NMAXTT) GO TO 250
      TGX=(TGX+GTT(N,M))*T
250   IF(N.GT.NMAXT) GO TO 260
      TGX=(TGX+GT(N,M))*T
260   TGX= TGX+G(N,M)
      TG(N,M)=TGX
 18   CONTINUE
      TLAST=TM
19    DLATR=DLAT/57.2957795D0
      SINLA=SIN(DLATR)
      RLONG=DLONG/57.2957795D0
```

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```
0120            CPH=COS(RLONG)
0121            SPH=SIN(RLONG)
0122            IF (J.EQ.0) GOTO20
        C
        C            Q IS GEOCENTRIC RADIUS WHEN J=1
        C
0123            R=Q
0124            CT=SINLA
0125            GO TO 21
0126    20      SINLA2=SINLA**2
        C
        C            Q IS GEODETIC ALTITUDE WHEN J=0
        C            ALT=Q
        C
0127            COSLA2=1.-SINLA2
0128            DEN2=A2-A2B2*SINLA2
0129            DEN=SQRT(DEN2)
0130            FAC=(((Q*DEN)+A2)/((Q*DEN)+B2))**2
0131            CT=SINLA/SQRT(FAC*COSLA2+SINLA2)
0132            R=SQRT(Q*(Q+2.*DEN)+(A4-A4B4*SINLA2)/DEN2)
0133    21      ST=SQRT(1.-CT**2)
0134            NMAX=MIN0(NMX,MAXN)
0135            NEXTF=NEXT
0136            CALL MAGF
0137            Y=BP
0138            F=B
0139            IF (J) 22,23,22
0140    22      X=-BT
0141            Z=-BR
0142            RETURN
        C       TRANSFORMS FIELD TO GEODETIC DIRECTIONS
0143    23      SIND=SINLA*ST-SQRT(COSLA2)*CT
0144            COSD=SQRT(1.0-SIND**2)
0145            X=-BT*COSD-BR*SIND
0146            Z=BT*SIND-BR*COSD
0147            RETURN
0148            END
```

```
      SUBROUTINE MAGF
      COMMON /COEFFS/G(10,10)
      COMMON/FLDCOM/ST,CT,SPH,CPH,R,NMAX,BT,BP,BR,B,ABAR,E1,E2,E3,NEXT
      DIMENSION P(10,10),DP(10,10),CONST(10,10),SP(10),CP(10),FN(10),FM(
     110)
      IF (P(1,1).EQ.1.0) GO TO 3
    1 P(1,1)=1.
      DP(1,1)=0.
      SP(1)=0.
      CP(1)=1.
      DO 2 N=2,10
      FN(N)=N
      DO 2 M=1,N
      FM(M)=M-1
    2 CONST(N,M)=FLOAT((N-2)**2-(M-1)**2)/FLOAT((2*N-3)*(2*N-5))
    3 SP(2)=SPH
      CP(2)=CPH
      DO 4 M=3,NMAX
      SP(M)=SP(2)*CP(M-1)+CP(2)*SP(M-1)
    4 CP(M)=CP(2)*CP(M-1)-SP(2)*SP(M-1)
      AOR=ABAR/R
      AR=AOR**2
      BT=0.
      BP=0.
      BR=0.
      DO 8 N=2,NMAX
      AR=AOR*AR
      DO 8 M=1,N
      IF (N-M) 6,5,6
    5 P(N,N)=ST*P(N-1,N-1)
      DP(N,N)=ST*DP(N-1,N-1)+CT*P(N-1,N-1)
      GO TO 7
    6 P(N,M)=CT*P(N-1,M)-CONST(N,M)*P(N-2,M)
C
C          NOTE : CONST(2,1)=0
C
      DP(N,M)=CT*DP(N-1,M)-ST*P(N-1,M)-CONST(N,M)*DP(N-2,M)
    7 PAR=P(N,M)*AR
      IF (M.EQ.1) GO TO 9
      TEMP=G(N,M)*CP(M)+G(M-1,N)*SP(M)
      BP=BP-(G(N,M)*SP(M)-G(M-1,N)*CP(M))*FM(M)*PAR
      GO TO 10
    9 TEMP=G(N,M)*CP(M)
   10 BT=BT+TEMP*DP(N,M)*AR
    8 BR=BR-TEMP*FN(N)*PAR
      BP=BP/ST
      IF(NEXT.GT.0) CALL EXTFLD
      B=SQRT(BT*BT+BP*BP+BR*BR)
      RETURN
      END
```

```
      SUBROUTINE EXTFLD
      COMMON/FLDCOM/ST,CT,SPH,CPH,R,NMAX,BT,BP,BR,B,ABAR,E1,E2,E3
      T1=E2*CPH+E3*SPH
      T2=E1*ST-T1*CT
      T1=E1*CT+T1*ST
      BR=BR-T1
      BP=BP+E2*SPH-E3*CPH
      BT=BT+T2
      RETURN
      END
```

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```
FORTRAN IV-PLUS V02-51E        15:20:13    15-OCT-82           PAGE 1
TOD.FTN          /TR:ALL/WR

0001            SUBROUTINE TOD(IMSOD,RHMS)
          C
          C     CONVERTS MILISECONDS OF THE DAY TO HOURS, MINUTES, SECONDS, AND
          C     THOUSANDTHS OF SECONDS.
          C         INTERMEDIATE VARIABLES ARE USED TO CONSERVE MULTIPLICATION
          C           THEREBY INCREASING SPEED.
          C
0002            INTEGER*4 IMSOD,IMSOH,IMSOM,IMSOS
          C
0003            IHOD=IMSOD/3600000
0004            IMSOH=IHOD*3600000
0005            IMOH=(IMSOD-IMSOH)/60000
0006            IMSOM=IMOH*60000
0007            ISOM=(IMSOD-IMSOH-IMSOM)/1000
0008            IMSOS=ISOM*1000
0009            ITOS=IMSOD-IMSOH-IMSOM-IMSOS
0010            RHMS=IHOD*10000.+IMOH*100.+ISOM+ITOS/1000.
0011            RETURN
          C
0012            END
```

```
C*************************************************************************)
C
C **** POSIT - GETS COORDINATES, CALLS STIROB AND SATPOS TO INTERPOLATE
C
C*************************************************************************)
C
      SUBROUTINE POSIT(IPOS,TM,IBMJD,ROREFT,SIDTM,TS,NOM2)
      COMMON /ORBCOM/ XTEM(5),YTEM(5),ZTEM(5)
      COMMON /ORBIT/ XX,YY,ZZ,SLAT,SLONG,SALT,IDAY,RHEM
      DIMENSION CO(3),POS(3)
      REAL*8 T,TM,TS
      INTEGER*4 IBMJD, JMSD, JDUM
      DATA PI / 3.14159265 /
      DATA ONE / 1.0 /
C
      K = INT(TM/60000 + 1)
      IF (K .LT. 3) K = 3
      IF (K .GT. NOM2) K = NOM2
C
      JJ = 0
10      JJ = JJ + 1
        KK = 2*(K+JJ) - 3
        READ (2'KK) JDUM,JMSD,CO
        IF (IPOS .LT. 3) GO TO 12
        RAD = SQRT(CO(1)**2 + CO(2)**2 + CO(3)**2)
        KK = KK + 1
        READ (2'KK) JDUM,JMSD,FLAT,HR,DLAT
        IF (IPOS .LE. 3) GO TO 11
        IF ((IPOS.GT.3).AND. (FLAT.LE.30.)) GO TO 100
        IF ((IPOS.GT.3).AND.(SIGN(ONE,DLAT).NE.SIGN(ONE,RHEM)))
     1  GO TO 100
        IPOS = 4
C
C **** CONVERT TO MAGNETIC INVARIANT COORDINATES
C
11      CO(1) = RAD*(COS(HR*PI/12.))*COS(FLAT*PI/180.)
        CO(2) = RAD*(SIN(HR*PI/12.))*COS(FLAT*PI/180.)
        CO(3) = RAD*SIN(FLAT*PI/180.)
12      XTEM(JJ) = CO(1)
        YTEM(JJ) = CO(2)
        ZTEM(JJ) = CO(3)
        IF (JJ .EQ. 3) T = JMSD - TS
      IF (JJ .LT. 5) GO TO 10
C
      DELT = TM - T
      IF (DELT .LT. -120000.) DELT = DELT + IDAY*86400000.
      IF (DELT .GT.  120000.) DELT = DELT - IDAY*86400000.
      CALL STIROB (DELT,IFLG)
      POS(1) = XX
      POS(2) = YY
      POS(3) = ZZ
      DELTDY = IBMJD - ROREFT + IDAY
      DFRADY = (TM + TS - IDAY*86400000.)/86400000.
      SIDTM = SIDTM
      CALL SATPOS (IPOS,POS,DELTDY,DFRADY,SIDTM)
      GO TO 101
```

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```
0044      100   IPOS = 5
0045      101   RETURN
0046            END
```

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```
C*************************************************************************)
C
C **** STIROB - INTERPOLATES POSITION GIVEN FIVE COORDINATES
C
C*************************************************************************)
C
      SUBROUTINE STIROB (DT,IFLG)
      COMMON /ORBCOM/ XTEM(5),YTEM(5),ZTEM(5)
      COMMON /ORBIT/ XX,YY,ZZ,SLAT,SLONG,SALT,IDAY
      DIMENSION DFX(5,5),DFY(5,5),DFZ(5,5)
C
      IFLG = 0
      U = DT/60000.
      U2 = U/2.
      U3 = U*U2
      U4 = (U2/3.)*(U3-.5)
      U5 = U2*U4
C
      DO 2 I = 1, 5
         IF (XTEM(I) .GT. 99999.) GO TO 50
         DFX(I,1) = XTEM(I)
         DFY(I,1) = YTEM(I)
         DFZ(I,1) = ZTEM(I)
2     CONTINUE
C
      DO 20 L = 2, 5
         N2 = 6 - L
         DO 20 N = 1, N2
            DFX(N,L) = DFX(N+1,L-1) - DFX(N,L-1)
            DFY(N,L) = DFY(N+1,L-1) - DFY(N,L-1)
            DFZ(N,L) = DFZ(N+1,L-1) - DFZ(N,L-1)
20    CONTINUE
C
      XX = DFX(3,1) + U2*(DFX(2,2)+DFX(3,2)) + U3*DFX(2,3)
     1           + U4*(DFX(1,4) + DFX(2,4)) + U5*DFX(1,5)
C
      YY = DFY(3,1) + U2*(DFY(2,2)+DFY(3,2)) + U3*DFY(2,3)
     1           + U4*(DFY(1,4)+DFY(2,4)) + U5*DFY(1,5)
C
      ZZ = DFZ(3,1) + U2*(DFZ(2,2)+DFZ(3,2)) + U3*DFZ(2,3)
     1           + U4*(DFZ(1,4)+DFZ(2,4)) + U5*DFZ(1,5)
C
C
      RETURN
C
50    IFLG = 1
      RETURN
      END
```

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```
C*************************************************************************)
C
C  **** SATPOS - FINDS LATITUDE, LONGITUDE, AND RADIUS FROM X,Y,Z
C
C*************************************************************************)
C
            SUBROUTINE SATPOS (IPOS,POS,DELTDY,DFRADY,SIDTM)
            COMMON /ORBIT/ XX,ZZ,YY,SLAT,SLONG,SALT,IDAY
            DIMENSION POS(3)
            DATA R360, R180 / 360., 180. /
C
            ROT = DFRADY*6.3003894 + DELTDY*.01720214 + SIDTM
            IF (IPOS .GE. 3) ROT = 0.
            TT = SQRT(POS(1)**2 + POS(2)**2)
            IF (TT .NE. 0.) GO TO 1
            RLONG = 0.
            SPN = 0.
            CPN = 1.
            GO TO 5
      1     CSA = POS(1)/TT
            SNA = POS(2)/TT
            SNL = SIN(ROT)
            CSL = COS(ROT)
            SPN = SNA*CSL - CSA*SNL
            CPN = SNA*SNL + CSA*CSL
C
            RLONG = 57.2957795*ATAN2(SPN,CPN)
C
            IF (IPOS .LT. 3) GO TO 2
            IF (RLONG .LT. 0) RLONG = 360. + RLONG
            GO TO 5
      2     IF(ABS(RLONG) .LE. 180.) GO TO 5
            RLONG = RLONG - SIGN(R360,RLONG)
            GO TO 2
      5     SLONG = RLONG
            R = SQRT(POS(1)**2 + POS(2)**2 + POS(3)**2)
C
            RZ = POS(3)/R
            RLAT = ASIN(RZ)*57.2957795
C
      7     IF (ABS(RLAT) .LE. 90.) GO TO 10
            RLAT = SIGN(R180,RLAT) - RLAT
            GO TO 7
     10     SLAT = RLAT
            SALT = R - 6371.0
C
            RETURN
            END
```

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```
FORTRAN IV-PLUS V02-51E          15:23:21     15-OCT-82             PAGE 1
TIME.FTN           /TR:ALL/WR

        C*************************************************************************)
        C
        C **** TIME - CONVERTS HOUR-MINUTE-SECOND OF DAY TO MILLISECOND OF DAY
        C
        C*************************************************************************)
        C
              SUBROUTINE TIME (RMSOD,RHMS,RTOS)
              REAL*8 RMSOD
              RH = AINT (RHMS/10000.)
              RM = AINT ((RHMS - RH*10000.)/100.)
              RS = AINT (RHMS - RH*10000. - RM*100.)
              RMSOD = 3600000.*RH + 60000.*RM + 1000.*(RS+RTOS)
              RETURN
              END
```

```
0001          SUBROUTINE YMDDOC(IYOC,IMOY,IDOM,IDOY,IDOC,IDOW)
        C     CONVERT YEAR-MONTH-DAY TO DAY OF CENTURY
        C     1900 JAN 01 = DOC 1900000
0002          INTEGER*4 IDOC
0003          COMMON IDPM(12)
        C
0004          IDOY=IDOM+IDPM(IMOY)
0005          YOC=IYOC
0006          ALEAP=YOC/4.0
0007          ILEAP=YOC/4.0
0008          IF(ALEAP.GT.ILEAP)GO TO 01510
0009          IF(ALEAP.EQ.(0.0))GO TO 01510
0010          IF(IMOY.LT.03)GO TO 01500
0011          IDOY=IDOY+001
0012    01500 IDOC=IYOC*365+ILEAP+IDOY-00002
0013          GO TO 01520
0014    01510 IDOC=IYOC*365+ILEAP+IDOY-00001
0015    01520 IDOW=IDOC-((IDOC+1)/7)*7+2
0016          RETURN
        C
0017          END
```

```
FORTRAN IV-PLUS V02-51E        15:23:36    15-OCT-82          PAGE 1
DOCYMD.FTN       /TR:ALL/WR

0001            SUBROUTINE DOCYMD(IDOC,IYOC,IMOY,IDOM,IDOY,IDOW)
          C     CONVERT DAY OF CENTURY (DOC) T O YEAR-MONTH-DAY (YMD)
          C
0002            INTEGER*4 IDOC
0003            COMMON IDPM(12)
          C
0004            IDOW=IDOC-((IDOC+1)/7)*7+2
0005            DOC=(IDOC+00001)*100
0006            IYOC=DOC/36525.0
0007            YOC=IYOC
0008            ALEAP=YOC/4.0
0009            ILEAP=YOC/4.0
0010            IDOY=IDOC+00001-IYOC*365-ILEAP
0011            IF(ALEAP.GT.ILFAP)GO TO 32000
0012            IF(ALEAP.EQ.(0.0))GO TO 32000
0013            IDOY=IDOY+001
0014      32000 MPY=13
0015      32500 MPY=MPY-01
0016            IF(ALEAP.GT.ILFAP)GO TO 32600
0017            IF(ALEAP.EQ.(0.0))GO TO 32600
0018            IF(IDOY.LT.060)GO TO 32600
0019            IF(IDOY.GT.(IDPM(MPY)+001))GO TO 33200
0020            GO TO 32500
0021      32600 IF(IDOY.GT.IDPM(MPY))GO TO 33000
0022            GO TO 32500
0023      33000 IDOM=IDOY-IDPM(MPY)
0024            GO TO 33500
0025      33200 IF(IDOY.LT.061)GO TO 33000
0026            IDOM=IDOY-(IDPM(MPY)+001)
0027      33500 IMOY=MPY
0028            RETURN
          C
0029            END
```

```
C***********************************************************************)
C
C **** CURDIS DEFINES A CURRENT DISTRIBUTION ARRAY AND
C **** PUTS IT INTO A DATA FILE, DIS.DAT
C
C***********************************************************************)
C
        DIMENSION CL(2,6), SCL(2,6), CCL(2,6), TCL(2,6)
        DIMENSION CLI(2,6), CMU(2,6), SMU(2,6), TMU(2,6)
        DIMENSION RZF(2,6), RB(2,6), RT(2,6)
        DIMENSION RZI(5), RZE(5), REJ(5)
        DIMENSION RI(2,6)
        DIMENSION AMPS(2,5,72), TP(4,6,72)
        DIMENSION AMPR(72),TPR(72)
        REAL*4 LAMBDA
        DATA PI / 3.14159265 /
        DATA RE / 6371000. /
        DATA ALTI / 120000. /
C
C***********************************************************************)
C
        WRITE (5,01000)
01000   FORMAT (' ENTER NUMBER OF CELL RINGS ')
        READ (5,*) NUMT
C
        WRITE (5,01010)
01010   FORMAT (' ENTER NUMBER OF CELLS PER 360 DEG LONGITUDE ')
        READ (5,*) NUML
C
        WRITE (5,01020)
01020   FORMAT(' ENTER INNER AND OUTER COLATITUDES OF RING ')
        READ (5,*) CL1, CL2
C
        WRITE (5,01040)
01040     FORMAT(' ENTER MAX RADIUS OF CURRENT FILAMENTS AND ')
        WRITE (5,01050)
01050   FORMAT(' LATITUDINAL THICKENING EXPONENT ')
        READ (5,*) RF, DF
C
        WRITE (5,01060)
01060   FORMAT ( ' ENTER MODEL NUMBER ' )
        READ (5,*) NCODE
C
C***********************************************************************)
C
C **** LOOP 10000 DEFINES THICKNESS OF CURRENT FILAMENTS:
C ****   FOR F-A CURRENTS SUPPLYING E-W CURRENTS ON I = 1;
C ****   FOR N-S CURRENTS ON I = 2;
C ****   FOR E-W CURRENTS ON I = 3.
C
        DO 10000 I = 2, 4
           DO 10000 J = 1, NUMT
              DO 10000 K = 1, NUML
                 TP(I,J,K) = 1.089/((((((J-.5)*(CL2-CL1)
     1                     /NUMT + CL1)/CL2)**DF)*(RF**2))
10000   CONTINUE
```

```
C
C **** LOOP 20000 DEFINES THICKNESS OF CURRENT FILAMENTS
C **** FOR F-A CURRENTS SUPPLYING N-S CURRENTS.
C
      N = NUMT + 1
      DO 20000 J = 1, N
         DO 20000 K = 1, NUML
            TP(1,J,K) = 1.E89/((((((J-1)*(CL2-CL1)/NUMT + CL1)
     1                  /CL2)**DF)*(RF**2))
20000 CONTINUE
C
C***********************************************************************)
C
C **** LOOPS 30000 AND 40000 DEFINE CURRENT PER LOOP FOR N-S AND E-W RESP.
C
      DO 30000 J = 1,NUMT
         DO 30000 K = 1, NUML
            S = -1./2.
            IF (K.GT.NUML/2.) S = 1./2.
            AMPS(1,J,K) = S
30000 CONTINUE
      DO 40000 J = 1,NUMT
         DO 40000 K = 1, NUML
            S=0.
            IF (K .GT. 12.*NUML/24.) S = 0.
            AMPS(2,J,K) = S
40000 CONTINUE
C
C***********************************************************************)
C
C **** LOOPS 50000 AND 60000 DEFINE LENGTH OF CURRENT FILAMENTS
C **** AND THEIR LOCATION IN SPACE
C
      DO 50000 I = 1, 2
         DO 50000 J = 1, N
            CL(I,J) = ((CL2-CL1)*(I*J-1)/(I*NUMT) + CL1)*PI/180.
            SCL(I,J) = SIN(CL(I,J))
            CCL(I,J) = COS(CL(I,J))
            TCL(I,J) = TAN(CL(I,J))
            CLT(I,J) = ATAN(2./TCL(I,J))
            CMU(I,J) = SIN(CLT(I,J) - CL(I,J))
            SMU(I,J) = COS(CLT(I,J) - CL(I,J))
            TMU(I,J) = 1./TAN(CLT(I,J) - CL(I,J))
            RZF(I,J) = (RE + ALTI)*(CCL(I,J) - SCL(I,J)/TMU(I,J))
            RB(I,J) = (RE + ALTI)*CCL(I,J)/SMU(I,J)
            RT(I,J) = (RE + ALTI)*3.
50000 CONTINUE
C
      DO 60000 K = 1, NUMT
         RZT(K) = (RE + ALTI)*(COS(CL(1,K)-CL(2,K)))/CCL(2,K)
         RI(1,K) = RZT(K)*SCL(2,K)
     1         - (RE + ALTI)*SIN(CL(2,K)- CL(1,K))
         RI(2,K) = RI(1,K) + 2.*(RE + ALTI)
     1         *SIN(CL(2,K) - CL(1,K))
         RZE(K) = RE + ALTI
         REJ(K) = RZE(K)*TAN(PI/NUML)
```

```
      60000 CONTINUE
C
C******************************************************************************)
C
C     **** LOOP 70000 DEFINES THE RING CURRENT
C
            RINGA=4.*RE
            RINGB=4.*RE*TAN(PI/NUML)
            DO 70000 I=1,NUML
               TPR(I)=1.E09/(1000**2)
               AMPR(I)=1.
      70000 CONTINUE
C
C******************************************************************************)
C
            OPEN (UNIT=1,NAME='DIS.DAT',TYPE='NEW')
            WRITE (1,*) NCODE, DF
            WRITE (1,*) CL1, CL2
            WRITE (1,*) NUMT, NUML
            WRITE (1,*) (((TB(I,J,K), K=1,NUML), J=1,N), I=1,4)
            WRITE (1,*) (((AMPS(I,J,K), K=1,NCOIL), J=1,NUMT), I=1,2)
            WRITE (1,*) ((RZF(I,J), J=1,N), I=1,2)
            WRITE (1,*) ((RB(I,J), J=1,N), I=1,2)
            WRITE (1,*) ((RT(I,J), J=1,N), I=1,2)
            WRITE (1,*) (RZI(K), K=1,NUMT)
            WRITE (1,*) (RZE(I), I=1,NUMT)
            WRITE (1,*) (REJ(I), I=1,NUMT)
            WRITE (1,*) ((RI(I,J), J=1,NUMT), I=1,2)
            WRITE (1,*) ((SCL(I,J), J=1,N), I=1,2)
            WRITE (1,*) ((CCL(I,J), J=1,N), I=1,2)
            WRITE (1,*) ((SMU(I,J), J=1,N), I=1,2)
            WRITE (1,*) ((CMU(I,J), J=1,N), I=1,2)
            WRITE (1,*) RINGA, RINGB
            WRITE (1,*) (TPR(I),I=1,NUML)
            WRITE (1,*) (AMPR(I),I=1,NUML)
            CLOSE (UNIT=1)
C
C******************************************************************************)
C
            STOP
            END
```

```
C*********************************************************************)
C
C **** AMPLT SHOWS CURRENT FLOWING THROUGH THE SURFACE OF A SPHERE
C **** JUST ABOVE THE IONOSPHERIC CURRENTS.
C **** EACH CIRCLE REPRESENTS A FIELD ALIGNED CURRENT FILAMENT AND
C **** ABOUT 90 PERCENT OF THE PLATICURTICALLY DISTRIBUTED  CURRENT
C **** IS THEREIN ENCLOSED.
C **** EACH LINE IN ONE OF THESE CIRCLES REPRESENTS ONE AMP (NUMBER
C **** OF LINES + OR - .5 IS CURRENT).
C
C*********************************************************************)
C
      DIMENSION AMP(2,5,72), TP(4,6,72)
      LOGICAL*1 DARRAY(11),FNUM(2)
      REAL*4 INCL, MLT
      DATA DARRAY / 'D', 'I', 'S', '.', 'D', 'A', 'T', ';', ' ', ' ',
     1 0 /
      DATA PI / 3.14159265 /
      DATA CF / 1.2594E-6 /
      DATA INCL, THTA / 'INCL', 'THTA' /
C
C*********************************************************************)
C
      WRITE (6,01000)
01000 FORMAT (' ENTER FILE NUMBER:NN')
      READ (6,01010) FNUM
01010 FORMAT (2A)
      DARRAY(9)=FNUM(1)
      DARRAY(10)=FNUM(2)
C
      WRITE (6,01020)
01020 FORMAT (' ENTER INCL AND THETA OF ORBIT: 0,0 FOR NO ORBIT ')
      READ (6,*) INCL, THTA
C
      SINCL = SIN(PI*INCL/180.)
      CINCL = COS(PI*INCL/180.)
      ST = SIN(PI*THTA/180.)
      CT = COS(PI*THTA/180.)
C
      CALL CALCMP(X,Y,2,0)
      CALL CALCMP(X,Y,0,2)
      XORG = 5.6
      YORG = 5.5
      CALL CALCMP(XORG,YORG,0,3)
C
C **** LOOP 10000 PLOTS THE ORBIT
C
      IF ((INCL .EQ. 0.) .AND. (THTA .EQ. 0.)) GO TO 10010
      DO 10000 I = 1, 150
         RMP = (I-1.)*2./149. - 1.
         SMP = SIN(30.*RMP*PI/180.)
         CMP = COS(30.*RMP*PI/180.)
         XL = ST*SMP + CT*CMP*SINCL
         YL = -CT*SMP - ST*CMP*SINCL
         ZL = CMP*CINCL
         GLAT = 180.*(ACOS(SQRT(XL**2+YL**2)))/PI
```

```
              Y = .15*(GLAT-90.)*YL/SQRT(XL**2+YL**2)
              X = .15*(GLAT-90.)*XL/SQRT(XL**2+YL**2)
              IF ( I .EQ. 1) CALL CALCMP(X,Y,0,1)
              CALL CALCMP(X,Y,1,1)
10000 CONTINUE
10010 CONTINUE
C
C*****************************************************************)
C
      OPEN (UNIT=1,NAME=DARRAY,TYPE='OLD')
      READ (1,*) NCODE
      READ (1,*) CL1, CL2
      READ (1,*) NUMT, NUML
      N = NUMT + 1
      READ (1,*) (((TP(I,J,K), K=1,NUML), J=1,N), I=1,4)
      READ (1,*) (((AMP(I,J,K), K=1,NUML), J=1,NUMT), I=1,2)
      CLOSE (UNIT=1)
C
C
      N = NUMT + 1
      DO 20000 NT = 1, 2
         DO 20000 I = 1, N
            DO 20000 J = 1, NUML
C
C:::::::::::::::::::::::::::::::::::::::::::::::::::::::::::::::::)
C
C **** THIS SECTION CALCULATES THE CURRENT PER FILAMENT
C
               IF((NT .EQ. 2) .AND. (I .EQ. N)) GO TO 20000
               F = ((I-1./NT)*(CL2-CL1)/NUMT + CL1)/30.
               XL = -4.5*F*COS(2.*(J+NT/2.-1.)*PI/NUML)
               YL = -4.5*F*SIN(2.*(J+NT/2.-1.)*PI/NUML)
               FAMP = AMP(1,I,J)
               IF((NT .EQ. 2) .AND. (J .LT. NUML))
     1         FAMP = AMP(2,I,J+1) - AMP(2,I,J)
               IF((NT .EQ. 2) .AND. (J .EQ. NUML))
     1         FAMP = AMP(2,I,1) - AMP(2,I,NUML)
               IF((NT .EQ. 1) .AND. (I .GT. 1))
     1         FAMP = AMP(1,I,J) - AMP(1,I-1,J)
               IF((NT .EQ. 1) .AND. (I .EQ. N)) FAMP = -AMP(1,NUMT,J)
               IF(FAMP .EQ. 0.) GO TO 20000
C
C:::::::::::::::::::::::::::::::::::::::::::::::::::::::::::::::::)
C
C **** LOOP 21000 CALCULATES THE RADIUS OF EACH FILAMENT
C **** AND DRAWS THE CIRCLE REPRESENTING IT.
C
               RF = SQRT(1.089/TP(NT,I,J))
               DO 21000 K = 1, 51
                  X = XL + RF*CF*SIN(K*PI/25.)
                  Y = YL - RF*CF*COS(K*PI/25.)
                  IF(K .EQ. 1) CALL CALCMP(X,Y,0,1)
                  CALL CALCMP(X,Y,1,1)
21000          CONTINUE
C
C:::::::::::::::::::::::::::::::::::::::::::::::::::::::::::::::::)
```

```
      C
      C **** LOOPS 22000 AND 23000 DRAW THE LINES IN EACH CIRCLE THAT
      C **** SHOW THE CURRENT IN EACH FILAMENT, 22000 FOR IN AND 23000 FOR OUT.
      C
                        IF(ABS(FAMP) .LT. .05) GO TO 20000
                        NLINE = INT(ABS(FAMP*10.) + .5)
                        IF(FAMP .LT. 0.) GO TO 20300
                        DO 22000 L = 1, NLINE
                           XW = RF*CF*SQRT(1.-(1.-L/((NLINE+1)/2.))**2)
                           X = XL - XW
                           Y = YL + RF*CF*(1.-L/((NLINE+1)/2.))
                           CALL CALCMP(X,Y,0,1)
                           X = XL + XW
                           Y = YL + RF*CF*(1.-L/((NLINE+1)/2.))
                           CALL CALCMP(X,Y,1,1)
      22000             CONTINUE
                        IF(FAMP .GT. 0.) GO TO 20000
      20300             DO 23000 M = 1, NLINE
                           YW = RF*CF*SQRT(1.-(1.-M/((NLINE+1)/2.))**2)
                           X = XL + RF*CF*(1.-M/((NLINE+1)/2.))
                           Y = YL - YW
                           CALL CALCMP(X,Y,0,1)
                           X = XL + RF*CF*(1.-M/((NLINE+1)/2.))
                           Y = YL + YW
                           CALL CALCMP(X,Y,1,1)
      23000             CONTINUE
      C
      C!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!)
      C
      20000 CONTINUE
      C
      C.........................................................................)
      C
      C **** LOOPS 30000 AND 40000 DRAW THE LATITUDE CIRCLES AND
      C **** MLT LINES AND LABELS RESPECTIVELY.
      C
            DO 30000 I = 1, 3
               DO 30000 J = 1, 51
                  X = 1.5*I*COS(J*PI/25.)
                  Y = 1.5*I*SIN(J*PI/25.)
                  IF(J .EQ. 1) CALL CALCMP(X,Y,0,1)
                  CALL CALCMP(X,Y,1,1)
      30000 CONTINUE
      C
            DO 40000 I = 1, 12
               TH = (I-1)*PI/6.
               ST = SIN(TH)
               CT = COS(TH)
               XL = 4.5*CT
               YL = 4.5*ST
               X = XL - 3.*CT
               Y = YL - 3.*ST
               CALL CALCMP(X,Y,0,1)
               X = XL
               Y = YL
               CALL CALCMP(X,Y,1,1)
```

```
               MLT = 2.*(I-1)
               XN = XL + .7*CT + .105
               YN = YL + .5*ST - .07
               IF (MLT .GT. 9) YN = YN - .14
               CALL NUMBER(XN,YN,.21,MLT,90.,-1)
      40000 CONTINUE
C
C************************************************************************)
C
C **** LOOP 50000 DRAWS TWO REPRESENTATIVE FILAMENT CROSS-SECTIONS
C **** ONE SHOWING CURRENT IN, THE OTHER, CURRENT OUT. EACH HAS
C **** A RADIUS OF 400000 METERS AND A CURRENT OF TEN AMPS.
C
            ROP = 400000.
            DO 50000 I = 1, 2
               GO TO (50010,50020) I
      50010    XL = 5.3
               YL = -2.5
               GO TO 50030
      50020    XL = 5.3
               YL = 1.9
      50030    DO 51000 J = 1, 51
                  X = XL + ROP*CF*SIN(J*PI/25.)
                  Y = YL - ROP*CF*COS(J*PI/25.)
                  IF(J .EQ. 1) CALL CALCMP(X,Y,0,1)
                  CALL CALCMP(X,Y,1,1)
      51000    CONTINUE
               GO TO (50040,50050) I
      50040    DO 52000 J = 1, 10
                  XW = ROP*CF*SQRT(1.-(1.-J/5.5)**2)
                  X = XL - XW
                  Y = YL + ROP*CF*(1.-J/5.5)
                  CALL CALCMP(X,Y,0,1)
                  X = XL + XW
                  Y = YL + ROP*CF*(1.-J/5.5)
                  CALL CALCMP(X,Y,1,1)
      52000    CONTINUE
               GO TO 50000
      50050    DO 53000 J = 1, 10
                  YW = ROP*CF*SQRT(1.-(1.-J/5.5)**2)
                  X = XL + ROP*CF*(1.-J/5.5)
                  Y = YL - YW
                  CALL CALCMP(X,Y,0,1)
                  X = XL + ROP*CF*(1.-J/5.5)
                  Y = YL + YW
                  CALL CALCMP(X,Y,1,1)
      53000    CONTINUE
      50000 CONTINUE
C
C************************************************************************)
C
            CALL SYMBOL(6.7,-5.07,.28,22HDISTRIBUTION OF FIELD ,90.,22)
            CALL SYMBOL(999.,999.,.28,16HALIGNED CURRENTS,90.,16)
            CALL SYMBOL(5.5,-1.9,.28,2HIN,90.,2)
            CALL SYMBOL(5.5,2.5,.28,3HOUT,90.,3)
            RCODE = NCODE
```

```
      CALL NUMBER(8.0,-5.07,.14,RCODE,90.,0)
      CALL NUMBER(999.,999.,.14,CL1,90.,0)
      CALL NUMBER(999.,999.,.14,CL2,90.,0)
      RUMT=NUMT
      CALL NUMBER(999.,999.,.14,RUMT,90.,0)
      RUML=NUML
      CALL NUMBER(999.,999.,.14,RUML,90.,0)
      CALL PAUS
      CALL CALCMP(X,Y,1000,2)
C
C**********************************************************************)
C
      STOP
      END
```

ORIGINAL PAGE IS
OF POOR QUALITY

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```
C*************************************************************************)
C
C  **** CURPLT SHOWS THE CURRENT VECTORS IN THE IONOSPHERE
C
C*************************************************************************)
C
      DIMENSION AMP(2,5,72), TP(4,6,72)
      LOGICAL*1 DARRAY(11),FNUM(2)
      REAL*4 MLT
      DATA DARRAY / 'D', 'I', 'S', ':', 'D', 'A', 'T', ';', ' ', ' ',
     1 0 /
      DATA PI / 3.14159265 /
C
C*************************************************************************)
C
      WRITE (6,01000)
01000 FORMAT (' ENTER FILE NUMBER:NN ')
      READ (6,01010) FNUM
01010 FORMAT (2A)
      DARRAY(9)=FNUM(1)
      DARRAY(10)=FNUM(2)
C
      WRITE (6,01020)
01020 FORMAT ( ' ENTER CURRENT MAGNITUDE ' )
      READ (6,*) CUR
C
      OPEN (UNIT=1,NAME=DARRAY,TYPE='OLD')
      READ (1,*) NCODE
      READ (1,*) CL1, CL2
      READ (1,*) NUMT, NUML
      N = NUMT + 1
      READ (1,*) (((TP(I,J,K), K=1,NUML), J=1,N), I=1,4)
      READ (1,*) (((AMP(I,J,K), K=1,NUML), J=1,NUMT), I=1,2)
      CLOSE (UNIT=1)
C
      CALL CALCMP(X,Y,1,0)
      CALL CALCMP(X,Y,0,2)
      XORG = 5.6
      YORG = 5.5
      CALL CALCMP(XORG,YORG,0,3)
C
C*************************************************************************)
C
C  **** LOOP 10000 DRAWS THE VECTORS AND THEIR HEADS
C
      DO 10000 I = 1, NUMT
        DO 10000 J = 1, NUML
C
C:::::::::::::::::::::::::::::::::::::::::::::::::::::::::::::::::::::::::)
C
C  **** THIS PART DRAWS THE VECTORS.
C
            F = (CL1 + (2.*I-1.)*(CL2-CL1)/(2.*NUMT))/30.
            XL = -4.5*F*COS(2.*(J-.5)*PI/NUML)
            YL = -4.5*F*SIN(2.*(J-.5)*PI/NUML)
            X = XL
```

```
                        Y = YL
                        CALL CALCMP(X,Y,0,1)
                        IF((AMP(1,I,J)**2 + AMP(2,I,J)**2) .EQ. 0.) GO TO 10000
                        XF = XL+CUR*(AMP(1,I,J)*XL-AMP(2,I,J)*YL)/SQRT(XL**2+YL**2)
                        YF = YL+CUR*(AMP(1,I,J)*YL+AMP(2,I,J)*XL)/SQRT(XL**2+YL**2)
                        X = XF
                        Y = YF
                        CALL CALCMP(X,Y,1,1)
C
C::::::::::::::::::::::::::::::::::::::::::::::::::::::::::::::::::::::::::::::)
C
C **** THIS PART DRAWS THE ARROW HEADS.
C
C
C                       TH = -ACOS(-(YL-YF)/SQRT((XL-XF)**2+(YL-YF)**2))
                        TH = ATAN2((XF-XL),(YL-YF))
                        X = XF - .12*SIN(TH - 20.*PI/180.)
                        Y = YF + .12*COS(TH - 20.*PI/180.)
                        CALL CALCMP(X,Y,1,1)
                        X = XF - .12*SIN(TH + 20.*PI/180.)
                        Y = YF + .12*COS(TH + 20.*PI/180.)
                        CALL CALCMP(X,Y,1,1)
                        X = XF
                        Y = YF
                        CALL CALCMP(X,Y,1,1)
C
C::::::::::::::::::::::::::::::::::::::::::::::::::::::::::::::::::::::::::::::)
C
10000 CONTINUE
C
C000000000000000000000000000000000000000000000000000000000000000000000000000000)
C
C **** LOOPS 50000 AND 60000 DRAW THE LATITUDE CIRCLES AND
C **** MLT LINES AND LABELS RESPECTIVELY.
C
            DO 50000 I = 1, 3
               DO 50000 J = 1, 51
                  X = 1.5*I*COS(J*PI/25.)
                  Y = 1.5*I*SIN(J*PI/25.)
                  IF(J .EQ. 1) CALL CALCMP(X,Y,0,1)
                  CALL CALCMP(X,Y,1,1)
50000 CONTINUE
C
            DO 60000 I = 1, 12
               TH = (I-1)*PI/6.
               ST = SIN(TH)
               CT = COS(TH)
               XL = 4.5*CT
               YL = 4.5*ST
               X = XL - 3.*CT
               Y = YL - 3.*ST
               CALL CALCMP(X,Y,0,1)
               X = XL
               Y = YL
               CALL CALCMP(X,Y,1,1)
               MLT = 2.*(I-1)
               XN = XL + .7*CT + .105
```

```
              YN = YL + .7*ST - .07
              IF (MLT .GT. 9) YN = YN - .14
              CALL NUMBER(XN,YN,.21,MLT,90.,-1)
      60000 CONTINUE
C
C*************************************************************************)
C
C
            CALL SYMBOL(6.4,-5.07,.28,16HDISTRIBUTION OF ,90.,16)
            CALL SYMBOL(999.,999.,.28,20HIONOSPHERIC CURRENTS,90.,20)
            RCODE = NCODE
            CALL NUMBER(8.0,-5.07,.14,RCODE,90.,0)
            CALL NUMBER(999.,999.,.14,CL1,90.,0)
            CALL NUMBER(999.,999.,.14,CL2,90.,0)
            RUMT = NUMT
            CALL NUMBER(999.,999.,.14,RUMT,90.,0)
            RUML = NUML
            CALL NUMBER(999.,999.,.14,RUML,90.,0)
            CALL PAUS
            CALL CALCMP(X,Y,1000,2)
C
C*************************************************************************)
C
            STOP
            END
```

```
C*******************************************************************************)
C
C **** BRKALC CALLS MAGMOD TO FIND CURRENT DENSITY AND MAGNETIC
C **** FIELD COMPONENTS OF THE BIRKELAND CURRENT MODEL DEFINED
C **** BY CURDIS AT POINTS ON A CIRCULAR ORBIT.
C
C*******************************************************************************)
C
            DIMENSION FLD(4), FTEM(3)
            COMMON /FILE/ CL1,CL2,NUMT,NUML,RF,TP(4,6,72),AMP(2,5,72),
          1RZF(2,6),RB(2,6),RT(2,6),RZI(5),RZE(5),REJ(5),RI(2,5),
          2SCL(2,6),CCL(2,6),SMU(2,6),CMU(2,6),
          3RINGA,RINGB,TPR(72),AMPR(72)
            LOGICAL*1 DARRAY(11),FNUM(2)
            REAL*4 INCL, MP
            DATA DARRAY / 'D', 'I', 'S', ':', 'D', 'A', 'T', '.', ' ', ' ',
          1 0 /
            DATA RE / 6371000. /
            DATA ALTI / 140000. /
            DATA PI / 3.14159265 /
C
            WRITE (5,01000)
      01000 FORMAT (' ENTER FILE NUMBER:NN ')
            READ (5,01010) FNUM
      01010 FORMAT (2A)
            DARRAY(9)=FNUM(1)
            DARRAY(10)=FNUM(2)
C
            WRITE (5,01020)
      01020 FORMAT (' ENTER ALTITUDE, INCLINATION, AND THETA ')
            READ (5,*) ALT, INCL, THETA
C
            WRITE (5,01030)
      01030 FORMAT (' ENTER NUMBER OF MEASUREMENT POINTS ')
            READ (5,*) NMEAS
C
            WRITE (5,01040)
      01040 FORMAT (' ENTER 1 FOR THE FIELD OF ALL CURRENTS'/
          1        '          2 FOR FIELD-ALIGNED ONLY'/
          2        '          3 FOR NORTH-SOUTH ONLY'/
          3        '          4 FOR EAST-WEST ONLY'/
          4        '          5 FOR RING CURRENT ONLY')
            READ (5,*) IFLD
C
            WRITE (5,01050)
      01050 FORMAT (' ENTER 1 FOR POLAR '/
          1        '          2 FOR EQUATORIAL WEST'/
          2        '          4 FOR EQUATORIAL EAST')
            READ (5,01060) IPASS
      01060 FORMAT (I)
            IF (IPASS.EQ.0) IPASS=1
C
            ST = SIN(THETA*PI/180.)
            CT = COS(THETA*PI/180.)
            SINCL = SIN(INCL*PI/180.)
            CINCL = COS(INCL*PI/180.)
```

```
C
      OPEN  (UNIT=1,NAME=DARRAY,TYPE='OLD')
      READ (1,*) NCODE, DF
      READ (1,*) CL1, CL2
      READ (1,*) NUMT, NUML
      N = NUMT + 1
      READ (1,*) (((TP(I,J,K), K=1,NUML), J=1,N), I=1,4)
      READ (1,*) (((AMP(I,J,K), K=1,NUML), J=1,NUMT), I=1,2)
      READ (1,*) ((RZF(I,J), J=1,N), I=1,2)
      READ (1,*) ((RB(I,J), J=1,N), I=1,2)
      READ (1,*) ((RT(I,J), J=1,N), I=1,2)
      READ (1,*) (RZI(I), I=1,NUMT)
      READ (1,*) (RZE(I), I=1,NUMT)
      READ (1,*) (REJ(I), I=1,NUMT)
      READ (1,*) ((RI(I,J), J=1,NUMT), I=1,2)
      READ (1,*) ((SCL(I,J), J=1,N), I=1,2)
      READ (1,*) ((CCL(I,J), J=1,N), I=1,2)
      READ (1,*) ((SMU(I,J), J=1,N), I=1,2)
      READ (1,*) ((CMU(I,J), J=1,N), I=1,2)
      READ (1,*) RINGA, RINGB
      READ (1,*) (TPR(I),I=1,NUML)
      READ (1,*) (AMPR(I),I=1,NUML)
      CLOSE (UNIT=1)
C
      OPEN (UNIT=1,NAME='MAG.DAT',TYPE='NEW')
      WRITE (1,*) NCODE,ALT
      WRITE (1,*) INCL,THETA
      WRITE (1,*) CL1,CL2
      WRITE (1,*) NUMT,NUML
      WRITE (1,*) NMEAS,IFLD
      WRITE (1,*) IPASS
C
      DO 10000 LX = 1, NMEAS
         MP = ((1. - (LX-1)*2./((NMEAS-1))*PI*40./180.
     1      -(IPASS-1)*270.*PI/180.
         SMP = SIN(MP)
         CMP = COS(MP)
         XL = (RE + ALT)*(-ST*SMP + CT*CMP*SINCL)
         YL = (RE + ALT)*(CT*SMP + ST*CMP*SINCL)
         ZL = (RE + ALT)*CMP*CINCL
         CALL MAGMOD(XL,YL,ZL,FLD,IFLD)
         WRITE (1,*) FLD
10000 CONTINUE
C
C************************************************************************)
C
      CLOSE (UNIT=1)
      STOP
      END
```

```
      C*********************************************************************)
      C
0001        SUBROUTINE MAGMOD (XL,YL,ZL,FLD,IFLD)
      C
      C **** CALCULATES CURRENT DENSITY AND MAGNETIC FIELD COMPONENTS
      C **** OF BIRKELAND CURRENT MODEL DEFINED BY CURDIS.
      C
      C*********************************************************************)
      C
0002        COMMON /FILE/ CL1,CL2,NUMT,NUML,RF,TP(4,6,72),AMP(2,5,72),
           1RZF(2,6),RB(2,6),RT(2,6),RZI(5),RZE(5),REJ(5),RI(2,5),
           2SCL(2,6),CCL(2,6),SMU(2,6),CMU(2,6),
           3RINGA,RINGB,TPR(72),AMPR(72)
0003        DIMENSION FAMP(6,72), RM(3,3), FLD(4)
0004        DIMENSION BF(3), BTF(3), BTI(3), BTE(3), BTR(3)
0005        REAL*4 LAMBDA, MP, JT
0006        DATA PI / 3.14159265 /
      C
0007        DO 10000 I = 1,3
0008           BTF(I) = 0.
0009           BTI(I) = 0.
0010           BTE(I) = 0.
0011           BTR(I) = 0.
0012  10000 CONTINUE
0013        JT = 0.
      C
0014        IF (IFLD.EQ.-2) GO TO 03000
0015        IF (IFLD.GT.2) GO TO 03000
      C
      C*********************************************************************)
      C
      C **** LOOP 20000 DOES THE FIELD ALIGNED CURRENTS SUPPLYING
      C **** BOTH THE E-W AND N-S IONOSPHERIC CURRENTS.
      C **** POSITIVE CURRENT IS VERTICAL.
      C
0016        I = NUMT + 1
0017        DO 20000 M = 1,2
0018          IF (M .EQ. 2) I = NUMT
0019          DO 20000 N = 1, I
0020            DO 20000 J = 1, NUML
0021            IF (M .EQ. 2) GO TO 20010
0022            FAMP(1,J) = AMP(1,1,J)
0023            FAMP(NUMT+1,J) = -AMP(1,NUMT,J)
0024            IF(N .EQ. (NUMT+1)) GO TO 20020
0025            IF(N .GT. 1) FAMP(N,J) = AMP(1,N,J) - AMP(1,N-1,J)
0026            IF(FAMP(N,J) .EQ. 0.) GO TO 20000
0027            GO TO 20020
0028  20010     FAMP(N,1) = AMP(2,N,NUML) - AMP(2,N,1)
0029            IF (J .GT. 1) FAMP(N,J) = AMP(2,N,J-1) - AMP(2,N,J)
0030            IF (FAMP(N,J) .EQ. 0) GO TO 20000
0031  20020     LAMBDA = 2.*(J-.5)*PI/NUML
0032            IF (M .EQ. 2) LAMBDA = 2.*J*PI/NUML
0033            SLA = SIN(LAMBDA)
0034            CLA = COS(LAMBDA)
      C
0035            RM(1,1) =  CLA*CMU(M,N)
```

```
                  RM(1,2) =  SLA*CMU(M,N)
                  RM(1,3) = -SMU(M,N)
                  RM(2,1) = -SLA
                  RM(2,2) =  CLA
                  RM(2,3) =  0.
                  RM(3,1) =  CLA*SMU(M,N)
                  RM(3,2) =  SLA*SMU(M,N)
                  RM(3,3) =  CMU(M,N)
C
                  XF = XL*RM(1,1) + YL*RM(1,2) + (ZL-RZF(M,N))*RM(1,3)
                  YF = XL*RM(2,1) + YL*RM(2,2) + (ZL-RZF(M,N))*RM(2,3)
                  ZF = XL*RM(3,1) + YL*RM(3,2) + (ZL-RZF(M,N))*RM(3,3)
C
                  RCF = XF**2 + YF**2
                  RBF = SQRT(RCF + (ZF-RB(M,N))**2)
                  RTF = SQRT(RCF + (ZF-RT(M,N))**2)
C
                  BXF = FAMP(N,J)*(TANH(RCF*TP(M,N,J)))*(YF/RCF)
         1             *((RT(M,N)-ZF)/RTF + (ZF-RB(M,N))/RBF)
                  BYF = -FAMP(N,J)*(TANH(RCF*TP(M,N,J)))*(XF/RCF)
         1             *((RT(M,N)-ZF)/RTF + (ZF-RB(M,N))/RBF)
                  DO 21000 IP = 1,3
                     BF(IP) = BXF*RM(1,IP) + BYF*RM(2,IP)
                     BTF(IP) = BTF(IP) + BF(IP)
      21000       CONTINUE
                  IF ((TP(M,N,J)*RCF) .GT. 40.) GO TO 20000
                  JT = FAMP(N,J)*TP(M,N,J)
         1           /(PI*((COSH(TP(M,N,J)*RCF))**2)) + JT
      20000 CONTINUE
C
            IF (IFLD.EQ.2) GO TO 07000
      03000 IF (IFLD.EQ.3) GO TO 04000
C
C*****************************************************************************)
C
            DO 30000 N = 1,NUMT
               DO 30000 J = 1,NUML
                  LAMBDA = 2.*(J-.5)*PI/NUML
                  SLA = SIN(LAMBDA)
                  CLA = COS(LAMBDA)
C
                  RM(1,1) =  CLA*CCL(2,N)
                  RM(1,2) =  SLA*CCL(2,N)
                  RM(1,3) = -SCL(2,N)
                  RM(2,1) = -SLA
                  RM(2,2) =  CLA
                  RM(2,3) =  0.
                  RM(3,1) =  CLA*SCL(2,N)
                  RM(3,2) =  SLA*SCL(2,N)
                  RM(3,3) =  CCL(2,N)
C
                  IF (IFLD.EQ.-3) GO TO 30100
                  IF (IFLD.EQ.4) GO TO 30100
C
C-----------------------------------------------------------------------------)
C
```

```
C **** THIS PART DOES THE NORTH-SOUTH IONOSPHERIC CURRENTS.
C **** NEGATIVE CURRENT IS NORTHWARD.
C
              IF(AMP(1,N,J) .EQ. 0.) GO TO 30010
C
              XF = XL*RM(1,1) + YL*RM(1,2) + (ZL-RZI(N))*RM(1,3)
              YF = XL*RM(2,1) + YL*RM(2,2) + (ZL-RZI(N))*RM(2,3)
              ZF = XL*RM(3,1) + YL*RM(3,2) + (ZL-RZI(N))*RM(3,3)
C
              RCF = YF**2 + ZF**2
              RI1 = SQRT(RCF + (XF - RI(1,N))**2)
              RI2 = SQRT(RCF + (XF - RI(2,N))**2)
C
              BYF = -AMP(1,N,J)*(TANH(100.*RCF*TP(3,N,J)))*(ZF/RCF)
     1              *(((XF-RI(1,N))/RI1) + (RI(2,N)-XF)/RI2)
              BZF = AMP(1,N,J)*(TANH(100.*RCF*TP(3,N,J)))*(YF/RCF)
     1              *(((XF-RI(1,N))/RI1) + (RI(2,N)-XF)/RI2)
              DO 31000 IP = 1,3
                 BF(IP) = BYF*RM(2,IP) + BZF*RM(3,IP)
                 BTI(IP) = BTI(IP) + BF(IP)
31000         CONTINUE
30010         CONTINUE
C
              IF (IFLD.EQ.-4) GO TO 30000
              IF (IFLD.EQ.3) GO TO 30000
C
C-----------------------------------------------------------------------)
C
C **** THIS PART DOES THE EAST-WEST ELECTROJETS.
C **** POSITIVE CURRENT IS EASTWARD.
C
30100         IF(AMP(2,N,J) .EQ. 0.) GO TO 30000
C
              XF = XL*RM(1,1) + YL*RM(1,2) + ZL*RM(1,3)
              YF = XL*RM(2,1) + YL*RM(2,2) + ZL*RM(2,3)
              ZF = XL*RM(3,1) + YL*RM(3,2) + ZL*RM(3,3)
C
              RCF = XF**2 + (ZF - RZE(N))**2
              RE1 = SQRT(RCF + (YF + REJ(N))**2)
              RE2 = SQRT(RCF + (YF - REJ(N))**2)
C
              BXF = AMP(2,N,J)*(TANH(100.*RCF*TP(4,N,J)))
     1        *(ZF-RZE(N))*((YF+REJ(N))/RE1+(REJ(N)-YF)/RE2)/RCF
              BZF = -AMP(2,N,J)*(TANH(100.*RCF*TP(4,N,J)))
     1        *XF*((YF+REJ(N))/RE1+(REJ(N)-YF)/RE2)/RCF
              DO 32000 IP = 1,3
                 BF(IP) = BXF*RM(1,IP) + BZF*RM(3,IP)
                 BTE(IP) = BTE(IP) + BF(IP)
32000         CONTINUE
30000 CONTINUE
C
        IF (IFLD.LE.1) GO TO 04000
        IF (IFLD.LT.5) GO TO 07000
C.......................................................................)
C
04000 IF (IFLD.EQ.-5) GO TO 07000
```

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```
C
C **** LOOP 40000 CALCULATES FIELD DUE TO RING CURRENT
C
      DO 40000 I=1,NUML
         LAMBDA=2.*(I-.5)*PI/NUML
         SLA=SIN(LAMBDA)
         CLA=COS(LAMBDA)
C
         RM(1,1)= CLA
         RM(1,2)= SLA
         RM(1,3)= 0.
         RM(2,1)=-SLA
         RM(2,2)= CLA
         RM(2,3)= 0.
         RM(3,1)= 0.
         RM(3,2)= 0.
         RM(3,3)= 1.
C
         IF (AMPR(I).EQ.0.) GO TO 40000
C
         XF=XL*RM(1,1) + YL*RM(1,2) + ZL*RM(1,3)
         YF=XL*RM(2,1) + YL*RM(2,2) + ZL*RM(2,3)
         ZF=XL*RM(3,1) + YL*RM(3,2) + ZL*RM(3,3)
C
         RCF=(XF-RINGA)**2 + ZF**2
         RR1=SQRT(RCF+(YF+RINGB)**2)
         RR2=SQRT(RCF+(YF-RINGB)**2)
C
         BXF=AMPR(I)*(TANH(RCF*TPR(I)))*ZF
     1      *((YF+RINGB)/RR1+(RINGB-YF)/RR2)/RCF
         BZF=-AMPR(I)*(TANH(RCF*TPR(I)))*(XF-RINGA)
     1      *((YF+RINGB)/RR1+(RINGB-YF)/RR2)/RCF
C
         DO 41000 IP=1,3
            BF(IP)=BXF*RM(1,IP)+BZF*RM(3,IP)
            BTR(IP)=BTR(IP)+BF(IP)
41000    CONTINUE
C
40000 CONTINUE
C
C **** LOOP 70000 ADDS FIELDS FROM ALL SOURCES AND CONVERTS TO S.I.
C
07000 DO 70000 IP = 1,3
         FLD(IP) = 200.*(BTF(IP)+BTI(IP)+BTE(IP)+BTR(IP))
70000 CONTINUE
      FLD(4) = JT
C
C*************************************************************************)
C
      RETURN
      END
```

```
FORTRAN IV-PLUS V02-51E          15:32:40    15-OCT-82           PAGE 1
BRKPLT.FTN        /TR:ALL/WR

      C*******************************************************************)
      C
      C **** BRKPLT PLOTS CURRENT DENSITY AND FIELD COMPONENTS
      C **** FOUND BY BRKALC.
      C
      C*******************************************************************)
      C
              DIMENSION FL(4,240), FTEM(3), FACT(4), FLD(4)
              DIMENSION FMAX(4)
              LOGICAL*1 ATEX(12),TEXT(8)
              LOGICAL*1 DARRAY(11),FNUM(2)
              REAL*4 ILAT, INCL, JT, JTMAX, MLT, MP, NAT
              DATA DARRAY / 'M', 'A', 'G', '.', 'D', 'A', 'T', ';', ' ', ' ',
             1 0 /
              DATA PI / 3.14159265 /
              DATA RE / 6371000. /
              DATA ALT / 140000. /
              DATA ATEX / 'X', 'Y', 'Z', 'J',
             1            'N', 'E', 'V', 'J',
             2            'S', 'D', 'V', 'J' /
      C
              WRITE (6,01000)
      01000   FORMAT (' ENTER FILE NUMBER:NN')
              READ (6,01010) FNUM
      01010   FORMAT (2A)
              DARRAY(9)=FNUM(1)
              DARRAY(10)=FNUM(2)
      C
              WRITE (6,01020)
      01020   FORMAT (' ENTER 1 FOR XYZ; 2 FOR NEV; 3 FOR SDV ')
              READ (6,*) MODE
      C
              OPEN(UNIT=1,NAME=DARRAY,TYPE='OLD')
              READ (1,*) NCODE,ALT
              READ (1,*) INCL, THETA
              READ (1,*) CL1, CL2
              READ (1,*) NUMT, NUML
              READ (1,*) NMEAS,IFLD
              READ (1,*) IPASS
              DO 10000 J = 1,NMEAS
                 READ (1,*) FLD
                 DO 10000 I = 1,4
                    FL(I,J) = FLD(I)
      10000   CONTINUE
              CLOSE (UNIT=1)
      C
              SINCL = SIN(PI*INCL/180.)
              CINCL = COS(PI*INCL/180.)
              ST = SIN(PI*THETA/180.)
              CT = COS(PI*THETA/180.)
      C
              IF (MODE .LE. 1) GO TO 11111
      C
      C*******************************************************************)
      C
      C **** CONVERT TO NEV ON 2; SDV ON 3
```

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```
C
      DO 11000 J = 1, NMEAS
        MP = (1.-(J-1)*2./(NMEAS-1))*PI*40./180.
     1     -(IPASS-1)*270.*PI/180.
        SMP = SIN(MP)
        CMP = COS(MP)
        XL  = -ST*SMP + CT*CMP*SINCL
        YL  =  CT*SMP + ST*CMP*SINCL
        ZL  =  CMP*CINCL
        FTEM(1) = FL(1,J)
        FTEM(2) = FL(2,J)
        FTEM(3) = FL(3,J)
        Q1 = SQRT(XL**2 + ZL**2)
        Q2 = SQRT(YL**2 + ZL**2)
        Q3 = SQRT(XL**2 + YL**2)
C
        FL(3,J) = -FTEM(1)*XL - FTEM(2)*YL - FTEM(3)*ZL
C
        IF (MODE .EQ. 3) GO TO 11010
C
        FL(1,J) = -FTEM(1)*XL*ZL/Q3 - FTEM(2)*YL*ZL/Q3 + FTEM(3)*Q3
        FL(2,J) = -FTEM(1)*YL/Q3 + FTEM(2)*XL/Q3
        GO TO 11000
11010   FL(1,J) = ( FTEM(1)*ZL + FTEM(3)*XL)/Q1
        FL(2,J) = (-FTEM(2)*ZL - FTEM(3)*YL)/Q2
11000 CONTINUE
C
C**********************************************************************)
C
C **** FIND MAXIMA
C
11111 DO 12000 I = 1,4
        DO 12000 J = 1,NMEAS
          FMAX(I) = AMAX1(ABS(FL(I,J)),FMAX(I))
12000 CONTINUE
      FMAX(1)=AMAX1(FMAX(1),FMAX(2))
      FMAX(2)=FMAX(1)
C
      CALL CALCMP(X,Y,2,0)
      CALL CALCMP(X,Y,0,2)
C
C**********************************************************************)
C
C **** PLOT BACKGROUND
C
      XORG = .15
      YORG = .1
      CALL CALCMP(XORG,YORG,0,3)
C
      DO 20000 I = 1,9
        X = 1.
        Y = (I-1)*1.2 + .8
        CALL CALCMP(X,Y,0,1)
        X = 11.
        Y = (I-1)*1.2 + .8
        CALL CALCMP(X,Y,1,1)
```

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```
FORTRAN IV-PLUS V02-51E          15:32:40    15-OCT-82            PAGE 3
BRKPLT.FTN        /TR:ALL/WR

                IF (I .EQ. 9) GO TO 20000
                DO 20000 J = 1,18
                   N = J
                   IF (J .GT. 9) N = J - 9
                   XL = 1.
                   IF (J .GT. 9) XL = 10.9
                   X = XL
                   Y = (N/10. + I - 1)*1.2 + .8
                   CALL CALCMP(X,Y,0,1)
                   X = .1 + XL
                   Y = (N/10. + I - 1)*1.2 + .8
                   CALL CALCMP(X,Y,1,1)
      20000 CONTINUE
C
C*************************************************************************)
C
C **** INDICATE GEOLAT, INVLAT, MLT
C
             DO 30000 I = 1, 6
                DO 30000 J = 5, 85, 5
                   G = (45-J)*PI/180.-(IPASS-1)*270.*PI/180.
                   GJ = 1.*J + 5.
                   SG = SIN(G)
                   CG = COS(G)
                   XL = -ST*SG + CT*CG*SINCL
                   YL =  CT*SG + ST*CG*SINCL
                   ZL =  CG*CINCL
                   RL = SQRT(XL**2 + YL**2)
C
                   GLAT = 180.*(ACOS(SQRT(XL**2+YL**2)))/PI
                   GLATR = GLAT*PI/180.
                   ILAT = 180.*(ACOS((SQRT(RE/(RE+ALT)))*COS(GLATR)))/PI
C
                   MLT = ASIN(YL/RL)*12./PI + 12.
                   IF ((XL .LT. 0.) .AND. (YL .GT. 0.))
          1        MLT = ASIN(-XL/RL)*12./PI + 18.
                   IF ((XL .LT. 0.) .AND. (YL .LT. 0.))
          1        MLT = ASIN(-YL/RL)*12./PI
                   IF ((XL .GT. 0.) .AND. (YL .LT. 0.))
          1        MLT = ASIN(XL/RL)*12./PI + 6.
C
                   W = 6. - (G+(IPASS-1)*270.*PI/180.)/.13962641
                   IF(I .EQ. 6) GO TO 30010
                   H = (I-1)*2.4 + .8
                   X = W
                   Y = -.05 + H
                   CALL CALCMP(X,Y,0,1)
                   X = W
                   Y = .05 + H
                   CALL CALCMP(X,Y,1,1)
                   GO TO 30000
      30010        IF (ABS(AMOD(GJ,10.)) .GT. 0.) GO TO 30000
                   H = .8
                   XN = W - .29
                   YN = H - .24
                   CALL NUMBER(XN,YN,.14,GLAT,0.,2)
```

```
                 XN = W - .29
                 YN = H - .45
                 CALL NUMBER(XN,YN,.14,ILAT,0.,2)
                 XN = W - .29
                 YN = H - .66
                 CALL NUMBER(XN,YN,.14,MLT,0.,2)
30000 CONTINUE
C
C*************************************************************************)
C
C **** DRAW LATITUDE CIRCLES
C
      CNORM=SIN(40.*PI/180.)
      IF (IPASS.GT.1) GO TO 64200
      DO 40000 I = 10,40,10
         CRAD=SIN(I*PI/180.)
         DO 40000 J = 1, 101
            X= CRAD*SIN(J*PI/50.)/CNORM+12.75
            Y=-CRAD*COS(J*PI/50.)/CNORM+8.6
            IF(J .EQ. 1) CALL CALCMP(X,Y,0,1)
            CALL CALCMP(X,Y,1,1)
40000    CONTINUE
C
C
C **** OR EQUATORIAL VIEW OF THE EARTH
C
      IF (IPASS.EQ.1) GO TO 65000
64200 CALL CALCMP (X,Y,1,-6)
      DO 42000 I=1,9
         CRAD=COS((I-5)*PI/18.)
         X=SIN((I-5)*PI/18.)/CNORM+12.75
         Y=CRAD/CNORM+8.6
         CALL CALCMP (X,Y,0,1)
         Y=-CRAD/CNORM+8.6
         CALL CALCMP (X,Y,1,1)
42000 CONTINUE
C
      DO 43000 I=10,190,10
         CRAD=COS((I-10)*PI/180.)
         DO 43000 J=1,81
            X=SIN((J-41)*PI/180.)/CNORM+12.75
            Y=CRAD*COS((J-41)*PI/180.)/CNORM+8.6
            IF (J.EQ.1) CALL CALCMP (X,Y,0,1)
            CALL CALCMP (X,Y,1,1)
43000 CONTINUE
      CALL CALCMP (X,Y,0,-6)
C
C*************************************************************************)
C
C **** INDICATE TIME
C
65000 IP=1
      IF (IPASS.GT.1) IP=2
      DO 60000 I = 1, 4
         S = SIN((I-1.)*PI/2.)
         C = COS((I-1.)*PI/2.)
```

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```
                IF (IPASS.GE.2) GO TO 50001
                X = .25*S + 12.75
                Y = -.25*C + 8.6
                CALL CALCMP(X,Y,0,1)
                X = S + 12.75
                Y = -C + 8.6
                CALL CALCMP(X,Y,1,1)
      50001     RNUM = (I-1)*6.
                GO TO (50010,50020,50030,50040) I
      50010     XL = 12.72
                YL = 7.4-(IP-1)*.6
                CALL NUMBER(XL,YL,.14,RNUM,0.,-1)
                GO TO 50000
      50020     XL = 13.82
                YL = 8.53
                IF (IPASS.GE.2) GO TO 50021
                CALL NUMBER(XL,YL,.14,RNUM,0.,-1)
                GO TO 50000
      50021     CALL SYMBOL (XL,YL,.14,1HN,0.,1)
                GO TO 50000
      50030     XL = 12.63+(IP-1)*.001
                YL = 9.87+(IP-1)*.6
                CALL NUMBER(XL,YL,.14,RNUM,0.,-1)
                GO TO 50000
      50040     XL = 11.45+(IP-1)*.15
                YL = 8.53
                IF (IPASS.GE.2) GO TO 50041
                CALL NUMBER(XL,YL,.14,RNUM,0.,-1)
                GO TO 50000
      50041     CALL SYMBOL (XL,YL,.14,1HS,0.,1)
      50000 CONTINUE
      C
      C**********************************************************************)
      C
      C **** PLOT ORBIT
      C
      06000 DO 60000 I = 1, NMEAS
                MP = (1.-(I-1)*2./(NMEAS-1))*PI*40./180.
           1         -(IPASS-1)*270.*PI/180.
                SMP = SIN(MP)
                CMP = COS(MP)
                XL = -ST*SMP + CT*CMP*SINCL
                YL =  CT*SMP + ST*CMP*SINCL
                ZL = CMP*CINCL
                X=-YL/CNORM+12.75
                Y= XL/CNORM+8.6
                IF (IPASS.GE.2) X=ZL/CNORM+12.75
                IF(I .EQ. 1) CALL CALCMP(X,Y,0,1)
                CALL CALCMP(X,Y,1,1)
      60000 CONTINUE
      C
            IF (MODE .GT. 1) GO TO 07000
      C
      C**********************************************************************)
      C
      C **** SHOW X,Y VECTORS
```

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```
C
               X = 11.58
               Y = 9.07
               CALL CALCMP(X,Y,0,1)
               X = 11.98
               Y = 9.07
               CALL CALCMP(X,Y,1,1)
               X = 11.98
               Y = 9.47
               CALL CALCMP(X,Y,1,1)
               CALL SYMBOL(11.82,9.5,.14,1HX,0.,1)
               CALL SYMBOL(11.42,9.07,.14,1HY,0.,1)
C
C********************************************************************)
C
C
C  **** INDICATE MAXIMA
C
07000  IPLT=4
       IF (IFLD.EQ.-2) IPLT=3
       IF (IFLD.GT.2) IPLT=3
       DO 70000 I = 1,IPLT
          FMAX(I)=FMAX(I)*10000.
          IF (I.EQ.4) FMAX(I)=FMAX(I)*1000000.
          IDEC=-1
          IF (FMAX(I).LT.10.) IDEC=1
          IF (FMAX(I).LT.1.) IDEC=2
          IF (FMAX(I).LT..1) IDEC=3
          FACT(I)=1.
70010     IF (FMAX(I).GE.10.) GO TO 70020
          IF (FMAX(I).LT.1.) GO TO 70030
          IF (FMAX(I).GE.1.) GO TO 70040
70020     FACT(I)=FACT(I)/10.
          FMAX(I)=FMAX(I)/10.
          GO TO 70010
70030     FACT(I)=FACT(I)*10.
          FMAX(I)=FMAX(I)*10.
          GO TO 70010
70040     IF (INT(FMAX(I)).LT.INT(FMAX(I)+.5)) GO TO 70050
          FMAX(I)=(AINT(FMAX(I))+.5)/FACT(I)
          GO TO 70060
70050     FMAX(I)=AINT(FMAX(I)+.5)/FACT(I)
C
70060     IF (FMAX(I).LT.1000.) ITY=1
          IF (FMAX(I).LT.100.) ITY=2
          IF (FMAX(I).LT.10.) ITY=1
          IF (FMAX(I).LT.1.) ITY=1
          IF (FMAX(I).LT..1) ITY=-1
          XL = 1.2
          YL = (5-I)*2.4 + .4
          N = I + (MODE-1)*4
          CALL SYMBOL (XL,YL,.28,ATEX(N),0.,1)
          IF (I .EQ. 4) CALL SYMBOL (999.,999.,.1,1HV,0.,1)
          XL = ITY*.14+.4
          YL = (5-I)*2.4 + .6
          CALL NUMBER (XL,YL,.14,FMAX(I),0.,IDEC)
          FM = 0.
```

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```
                XL=.8
                YL = (5-I)*2.4 - .47
                CALL NUMBER (XL,YL,.14,FM,0.,-1)
                FM=-FMAX(I)
                XL=ITY*.14+.26
                YL = (5-I)*2.4 - 1.55
                CALL NUMBER (XL,YL,.14,FM,0.,IDEC)
                XL=.2
                YL=(5-I)*2.4-1.1
                IF (I.EQ.4) GO TO 70070
                CALL SYMBOL (XL,YL,.14,10HNANOTESLAS,90.,10)
                GO TO 70080
      70070     YL=YL+.1
                CALL SYMBOL (XL,YL,.14,9HMICROAMPS,90.,9)
      70080     FMAX(I)=FMAX(I)/10000.
                IF (I.EQ.4) FMAX(I)=FMAX(I)/1000000.
      70000 CONTINUE
C
C******************************************************************************)
C
C **** PLOT FIELDS
C
            DO 80000 I = 1,IPLT
                IF ((I.EQ.4).AND.(ALT.LT.ALTI)) GO TO 80000
                DO 80000 J = 1,NMEAS
                    MP = (J-1)*2./(NMEAS-1)
                    X = 5.*MP + 1.
                    Y = 2.4*(4-I) + 2. + 1.2*FLK(I,J)/FMAX(I)
                    IF (J .EQ. 1) CALL CALCMP(X,Y,0,1)
                    IF (J .EQ. 1) GO TO 80000
                    CALL CALCMP(X,Y,1,1)
      80000 CONTINUE
C
C******************************************************************************)
C
            CALL CALCMP(0.,0.,0,3)
            CALL SYMBOL(0.,10.64,.35,21HB-FIELD OF BIRKELAND ,0.,21)
            CALL SYMBOL(999.,999.,.35,13HCURRENT MODEL,0.,13)
            CALL SYMBOL(0.,.66,.14,6HGEOLAT,0.,6)
            CALL SYMBOL(0.,0.45,.14,6HINVLAT,0.,6)
            CALL SYMBOL(0.,0.24,.14,3HMLT,0.,3)
            ORY=7.2
            IF (IPASS.GE.2) ORY=6.5
            CALL SYMBOL(12.55,ORY,.14,5HORBIT,0.,5)
            CALT = ALT/1000.
            CALL SYMBOL(11.7,6.0,.14,17HALTITUDE =      KM,0.,17)
            CALL NUMBER(13.2,6.0,.14,CALT,0.,-1)
            RCODE = NCODE
            CALL NUMBER(12.,0.,.14,RCODE,0.,0)
            CALL NUMBER(999.,999.,.14,CL1,0.,0)
            CALL NUMBER(999.,999.,.14,CL2,0.,0)
            RUMT=NUMT
            CALL NUMBER(999.,999.,.14,RUMT,0.,0)
            RUML=NUML
            CALL NUMBER(999.,999.,.14,RUML,0.,0)
            RFLD=IFLD
```

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```
0305              CALL NUMBER(999.,999.,.14,RFLD,0.,0)
            C
            C**************************************************************************)
            C
0306              CALL PAUS
0307              CALL CALCMP(X,Y,1000,2)
            C
0308              STOP
0309              END
```

```
        C*********************************************************************)
        C
        C **** 3DBRKC CALLS MAGMOD TO FIND CURRENT DENSITY AND MAGNETIC
        C **** FIELD COMPONENTS OF THE BIRKELAND CURRENT MODEL DEFINED BY
        C **** CURDIS AT POINTS ON A SPHERE OF RADIUS 'ALTI' GREATER THAN
        C **** THE EARTH'S.
        C
        C*********************************************************************)
        C
0001          DIMENSION FLD(4), FTEM(3)
0002          COMMON /FILE/ CL1,CL2,NUMT,NUML,RE,TP(4,6,72),AMP(2,5,72),
             1RZF(2,6),RB(2,6),RT(2,6),RZI(5),RZE(5),REJ(5),RI(2,5),
             2SCL(2,6),CCL(2,6),SMU(2,6),CMU(2,6),
             3RINGA,RINGB,TPR(72),AMPR(72)
0003          LOGICAL*1 DARRAY(11),FNUM(2)
0004          DATA DARRAY / 'D', 'I', 'B', ':', 'D', 'A', 'T', ';', ' ', ' ',
             1 0 /
0005          DATA RE / 6371000. /
0006          DATA PI / 3.14159265 /
0007          DATA ALTI / 140000. /
        C
0008          OPEN (UNIT=1,NAME='3DBRKC.DAT',FORM='FORMATTED',
             1TYPE='OLD')
0009          READ (1,01000) ALT
0010    01000 FORMAT (1X,F9.1)
        C
0011          READ (1,01010) IFLD
0012    01010 FORMAT (1X,I2)
        C
0013          READ (1,01020) FNUM
0014    01020 FORMAT (2A)
0015          DARRAY(9)=FNUM(1)
0016          DARRAY(10)=FNUM(2)
        C
0017          CLOSE (UNIT=1)
        C
0018          OPEN (UNIT=1,NAME=DARRAY,TYPE='OLD')
0019          READ (1,*) NCODE,DF
0020          READ (1,*) CL1, CL2
0021          READ (1,*) NUMT, NUML
0022          N = NUMT + 1
0023          READ (1,*) (((TP(I,J,K), K=1,NUML), J=1,N), I=1,4)
0024          READ (1,*) (((AMP(I,J,K), K=1,NUML), J=1,NUMT), I=1,2)
0025          READ (1,*) ((RZF(I,J), J=1,N), I=1,2)
0026          READ (1,*) ((RB(I,J), J=1,N), I=1,2)
0027          READ (1,*) ((RT(I,J), J=1,N), I=1,2)
0028          READ (1,*) (RZI(I), I=1,NUMT)
0029          READ (1,*) (RZE(I), I=1,NUMT)
0030          READ (1,*) (REJ(I), I=1,NUMT)
0031          READ (1,*) ((RI(I,J), J=1,NUMT), I=1,2)
0032          READ (1,*) ((SCL(I,J), J=1,N), I=1,2)
0033          READ (1,*) ((CCL(I,J), J=1,N), I=1,2)
0034          READ (1,*) ((SMU(I,J), J=1,N), I=1,2)
0035          READ (1,*) ((CMU(I,J), J=1,N), I=1,2)
0036          READ (1,*) RINGA,RINGB
0037          READ (1,*) (TPR(I),I=1,NUML)
```

```
        READ (1,*) (AMPR(I),I=1,NUML)
        CLOSE (UNIT=1)
C
C*****************************************************************************)
C
        OPEN (UNIT=2,NAME='3DMAG.DAT',ACCESS='DIRECT',
       1TYPE='NEW',RECORDSIZE=4)
C
        RCODE = NCODE
        RFLD=IFLD
        WRITE (2'1) ALT, RCODE, RFLD, DF
        DO 10000 ID = 1, 48
           GM = -(ID*80./47. - 40. - 80./47.)*PI/180.
           SGM = SIN(GM)
           CGM = COS(GM)
C
           DO 10000 IE = 1, 48
              GC = (IE*80./47. - 40. - 80./47.)*PI/180.
              SGC = SIN(GC)
              CGC = COS(GC)
              XL = (RE + ALT)*CGC*SGM
              YL = (RE + ALT)*SGC
              ZL = (RE + ALT)*CGC*CGM
              CALL MAGMOD (XL,YL,ZL,FLD,IFLD)
C
C **** CONVERT FROM X,Y,Z TO S,D,V
C
              FTEM(1) = FLD(1)
              FTEM(2) = FLD(2)
              FTEM(3) = FLD(3)
C
              Q1 = SQRT(XL**2 + ZL**2)
              Q2 = SQRT(YL**2 + ZL**2)
              QQ = SQRT(XL**2 + YL**2 + ZL**2)
C
              FLD(1) = ( FTEM(1)*ZL + FTEM(3)*XL)/Q1
              FLD(2) = (-FTEM(2)*ZL - FTEM(3)*YL)/Q2
              FLD(3) = (-FTEM(1)*XL - FTEM(2)*YL - FTEM(3)*ZL)/QQ
C
              IT = 2 + IE + (ID - 1)*48
              WRITE (2'IT) FLD
10000   CONTINUE
        CLOSE (UNIT=2)
C
C*****************************************************************************)
C
        STOP
        END
```


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```
C***********************************************************************)
C
C **** 3DPLT PLOTS ARRAYS IN 3-D PERSPECTIVE
C
C***********************************************************************)
C
C **** SUBROUTINE CREAD READS AND CONDITIONS DATA
C
      SUBROUTINE CREAD (MATVEC,NRW,NCOL,NERR)
      DIMENSION MATVEC(2304),RATVEC(4)
      LOGICAL*1 FNAM(14)
      REAL*4 MAXVEC,MINVEC
      COMMON /FILE/ VECMUL,ZMN,FNAM,MAXVEC,MINVEC,IVEC,ALT,RCODE
      NERR = 0
      ITOP = NRW*NCOL
C
      DO 10000 I = 1,ITOP
         MATVEC(I) = 0
10000 CONTINUE
C
      OPEN(UNIT=2,NAME=FNAM,TYPE='OLD',ACCESS='DIRECT')
C
      IF (FNAM(3).EQ.'M') GO TO 01000
C
      DO 11000 J = 1,2304
         READ(2'J) RATVEC(1)
         RATVEC(1)=RATVEC(1)-ZMN
         IF (RATVEC(1).LT.0.) RATVEC(1)=0.
         MATVEC(J) = VECMUL*RATVEC(1)
11000 CONTINUE
      GO TO 01010
C
01000 READ (2'1) ALT,RCODE,RUMT,RUML
      MAXVEC=0.
      MINVEC=0.
C
      DO 12000 J=2,2305
         READ (2'J) RATVEC
         MAXVEC=AMAX1(MAXVEC,RATVEC(IVEC))
         MINVEC=AMIN1(MINVEC,RATVEC(IVEC))
         MATVEC(J-1)=INT(VECMUL*RATVEC(IVEC))
12000 CONTINUE
C
01010 RETURN
      END
```

```
C
C**********************************************************************)
C
C **** MAIN PROGRAM
C
      DIMENSION D(48,48),YM(200),XM(200),YMP(200),XMP(200),YPL(2,200),
     1XPL(2,200)
      LOGICAL*1 FNAM(14),NAM(6),NUM(2),DAT(5)
      REAL*4 MAXVEC,MINVEC
      COMMON D,XSC,YSC,ZSC,CA1,SA1,CA2,SA2,NX,NY,FOC,DIS,XV,YV
      COMMON /FILE/ VECMUL,ZMN,FNAM,MAXVEC,MINVEC,IVEC,ALT,RCODE
      EQUIVALENCE (NAM(6),FNAM(6))
      EQUIVALENCE (NUM(2),FNAM(13))
      EQUIVALENCE (DAT(5),FNAM(11))
      DATA DAT / '.','D','A','T',' ' /
C
90000 FORMAT(27H1OUT OF 'LAST LINE' STORAGE)
90010 FORMAT(28H1OUT OF LINE SEGMENT STORAGE)
C
      WRITE (5,80000)
80000 FORMAT ( ' ENTER FILE NAME (AAAAAA NN')
      READ (5,80010) NAM,NUM
80010 FORMAT (6A,1X,2A)
      FNAM(14)=0
C
      WRITE (5,80020)
80020 FORMAT (' ENTER VECMUL, ZMIN, XVIEW, YVIEW, IVEC ')
      READ (5,*) VECMUL,ZMN,XV,YV,IVEC
C
C
      WRITE (5,80030)
80030 FORMAT (' ENTER FOC AND DIS ')
      READ (5,*) FOC,DIS
C
      OPEN(UNIT=1,NAME='3DPLT.DAT',TYPE='OLD',FORM='FORMATTED')
C
C **** INITIALIZE PLOTTING PARAMETERS
C
99999 CALL DIN
      CALL UNIT(3)
      CALL CALCMP(0.,0.,2,0)
      CALL CALCMP(0.,0.,0,2)
      CALL CALCMP(0.,0.,0,3)
      CALL CALCMP(1.,.2,4,-6)
C
      IF (YV.GT.0.) GO TO 00001
      S02=XSC*(NX-1)*SA1*CA2+DIS+FOC
      VX2=XSC*(NX-1)*CA1/(S02/FOC-1.)
      S04=YSC*(NY-1)*CA1*CA2+DIS+FOC
      VX4=-YSC*(NY-1)*SA1/(S04/FOC-1.)
      VY3=XSC*(NX-1)*SA1*SA2/(S02/FOC-1.)
     1    +YSC*(NY-1)*CA1*SA2/((S02+S04)/FOC-1.
      XV=VX2-(VX2-VX4)/2.
      YV=VY3/2.
00001 WRITE (3,80100) MAXVEC,MINVEC
80100 FORMAT (' MAXVEC = ',1PE7.1,'NT  MINVEC = ',1PE8.1,'NT')
```

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```
      IF (FNAM(3).NE.'M') GO TO 00002
      WRITE (3,80110) IVEC
80110 FORMAT ('  VECTOR = ',I2)
      WRITE (3,80120) RCODE,ALT
80120 FORMAT ('  DIS-CODE = ',F4.0,'  ALTITUDE = ',1PE7.1,'M')
00002 CALL MDCHNG(4,X,Y)
      CALL WINDEW (0.,14.,-7.,7.,.5,11.,-4.75,5.75,1)
C
C **** BEGIN PLOTTING
C
      CALL PTRA(1,NY,XP,YP)
      IF (FOC.EQ.0.) GO TO 00010
      S0=YSC*(NY-1.)*CA1*CA2+DIS+FOC
      YPB=(YSC*(NY-1.)*CA1*SA2)/(S0/FOC-1.)
      GO TO 00020
00010 YPB=YSC*(NY-1.)*CA1*SA2*DIS
00020 CALL CALCMP(XP,YPB,0,1)
      CALL CALCMP(XP,YP,1,1)
      XMP(1)=XP
      YMP(1)=YP
C
      DO 10000 I=2,NY
         N=NY-I+1
         CALL PTRA(1,N,XP,YP)
         CALL CALCMP(XP,YP,1,1)
         IF (FOC.EQ.0.) GO TO 10010
         S0=YSC*(N-1)*CA1*CA2+DIS+FOC
         YPB=(YSC*(N-1.)*CA1*SA2)/(S0/FOC-1.)
         GO TO 10020
10010    YPB=YSC*(N-1.)*CA1*SA2
10020    IF ((YP-YPB-.005).LE.0.) GO TO 10030
         CALL CALCMP(XP,YPB,1,1)
         CALL CALCMP(XP,YP,0,1)
10030    XMP(I)=XP
         YMP(I)=YP
10000 CONTINUE
C
      DO 11000 I=2,NX
         CALL PTRA(I,1,XP,YP)
         CALL CALCMP(XP,YP,1,1)
         IF (FOC.EQ.0.) GO TO 11010
         S0=XSC*(I-1.)*SA1*CA2+DIS+FOC
         YPB=(XSC*(I-1.)*SA1*SA2)/(S0/FOC-1.)
         GO TO 11020
11010    YPB=XSC*(I-1.)*SA1*SA2
11020    IF ((YP-YPB-.005).LE.0.) GO TO 11030
         CALL CALCMP(XP,YPB,1,1)
         CALL CALCMP(XP,YP,0,1)
11030    N=NY+I-1
         XMP(N)=XP
         YMP(N)=YP
11000 CONTINUE
C
      XPLST=0.
      YPLST=0.
      IPDR=-1
```

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```
              NXMP=N
              IXI=1
              IYI=1
        01000 IF (IYI.GE.NY) GO TO 01010
              IYI=IYI+1
              GO TO 02000
        01010 IXI=IXI+1
              IF (IXI.LT.NX) GO TO 02000
              CALL PAUS
              CALL PAUS
              CALL CALCMP(X,Y,1000,2)
              STOP
        C
        02000 IX=IXI
              IY=IYI
              IXD=1
              IYD=0
              NXPL=3
        02010 CALL PTRA(IX,IY,X1,Y1)
              IF (IXD.LE.0) GO TO 02110
              IXT=IX+1
              CALL PTRA(IXT,IY,X2,Y2)
              IYT=IY-1
              CALL PTRA(IXT,IYT,X3,Y3)
              YT=Y1+(X2-X1)*(Y3-Y1)/(X3-X1)
              IF (Y2.GE.YT) GO TO 02100
              CALL DIAG(IX,IY,INDG)
              IF (INDG.LE.0) GO TO 03000
              X2=X3
              Y2=Y3
              IX=IX+1
              IXD=0
              IYD=-1
              GO TO 03000
        C
        02100 IF (SA1.GT..6428) GO TO 03000
              CALL PTRA(IX,IYT,X4,Y4)
              YT=Y1+(X4-X1)*(Y2-Y1)/(X2-X1)
              IF (Y4.LE.YT) GO TO 03000
              CALL DIAG(IX,IY,INDG)
              IF (INDG.GT.0) GO TO 03000
              X1=X4
              Y1=Y4
              GO TO 03000
        C
        02110 IYT=IY-1
              CALL PTRA(IX,IYT,X2,Y2)
              IF (CA1.GT..6420) GO TO 03000
              IXT=IX-1
              CALL PTRA(IXT,IYT,X3,Y3)
              YT=Y1+(X3-X1)*(Y2-Y1)/(X2-X1)
              IF (Y3.LE.YT) GO TO 03000
              CALL DIAG(IXT,IY,INDG)
              IF (INDG.GT.0) GO TO 03000
              X2=X3
              Y2=Y3
```

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```
C
03000 I=1
03001 I=I+1
      IF (XMP(I).GT.X1) GO TO 03010
      IF (I.LT.NXMP) GO TO 03001
C
03010 C2=(Y2-Y1)/(X2-X1)
      C1=X1*C2-Y1
03020 C3=(YMP(I)-YMP(I-1))/(XMP(I)-XMP(I-1))
      XNUM=YMP(I-1)-XMP(I-1)*C3+C1
      XDEN=C2-C3
C
      IF (.001*ABS(XNUM).GE.ABS(XDEN)) GO TO 03100
      XT=XNUM/XDEN
      IF ((XT-X1).LE..001) GO TO 03100
      IF (XT.LE.XMP(I-1)) GO TO 03100
      IF ((XT-X2).GT.-.001) GO TO 03100
      IF (XT.GT.XMP(I)) GO TO 03100
      YT=C2*XT-C1
      GO TO 04000
03100 IF (X2.LE.XMP(I)) GO TO 03110
      IF (I.GE.NXMP) GO TO 03110
      I=I+1
      GO TO 03020
03110 XT=X2
      YT=Y2
C
04000 XTT=.5*(X1+XT)
      I=1
04010 I=I+1
      IF (XMP(I).GT.XTT) GO TO 04020
      IF (I.LT.NXMP) GO TO 04010
C
04020 YTT=YMP(I)+(XTT-XMP(I))*(YMP(I-1)-YMP(I))/(XMP(I-1)-XMP(I))
      IF (.5*(Y1+YT).LT.YTT) GO TO 05000
      NXPL=NXPL+1
      IF (NXPL.LE.200) GO TO 04030
      TYPE 90010
      STOP
C
04030 XPL(1,NXPL)=X1
      XPL(2,NXPL)=XT
      YPL(1,NXPL)=Y1
      YPL(2,NXPL)=YT
C
05000 IF ((XT-X2).GE.-.001) GO TO 05010
      X1=XT
      Y1=YT
      GO TO 03000
C
05010 IX=IX+IXD
      IY=IY+IYD
      IT=IYD
      IYD=-IXD
      IXD=-IT
      IF ((IX+IXD).GT.NX) GO TO 05020
```

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```
      IF (IY.GT.1) GO TO 02010
05020 IF (NXPL.LE.0) GO TO 05100
C
      DO 15000 J=1,NXPL
         IF (IPDR.GT.0) GO TO 15010
         IIPL=2
         JJPL=NXPL-J+1
         GO TO 15020
15010    IIPL=1
         JJPL=J
15020    XPLNX=XPL(IIPL,JJPL)
         YPLNX=YPL(IIPL,JJPL)
         IF (((XPLNX-XPLST)**2+(YPLNX-YPLST)**2).LE..0001) GO TO 15030
         CALL CALCMP(XPLNX,YPLNX,0,1)
15030    XPLST=XPL(IIPL+IPDR,JJPL)
         YPLST=YPL(IIPL+IPDR,JJPL)
         CALL CALCMP(XPLST,YPLST,1,1)
15000 CONTINUE
C
      IPDR=-IPDR
05100 NXM=0
      XLST=-1000.
      IXMP=1
      IXPL=0
05110 IXPL=IXPL+1
      IF (IXPL.GT.NXPL) GO TO 05120
      IF ((ABS(XLST-XPL(1,IXPL))).LE..001) GO TO 06010
05120 IF ((XMP(IXMP)-XLST).GT..001) GO TO 05140
05130 IXMP=IXMP+1
      IF (IXMP.LE.NXMP) GO TO 05120
      IF (IXPL-NXPL) 05150,06050,06050
05140 IF (IXPL.GT.NXPL) GO TO 06040
      IF ((XMP(IXMP)-XPL(1,IXPL)).GE.-.001) GO TO 06020
      NXM=NXM+1
      IF (NXM.LE.200) GO TO 06000
05150 TYPE 90000
      STOP
C
06000 XLST=XMP(IXMP)
      XM(NXM)=XLST
      YM(NXM)=YMP(IXMP)
      GO TO 05130
06010 NXM=NXM+1
      IF(NXM-200)06030,06030,05150
06020 NXM=NXM+2
      IF (NXM.GT.200) GO TO 05150
      XM(NXM-1)=XPL(1,IXPL)
      YM(NXM-1)=YPL(1,IXPL)
06030 XLST=XPL(2,IXPL)
      XM(NXM)=XLST
      YM(NXM)=YPL(2,IXPL)
      GO TO 05110
C
06040 I=IXMP
06041 I=I+1
      NXM=NXM+1
```

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```
              IF (NXM.GT.200) GO TO 05150
              XM(NXM)=XMP(I)
              YM(NXM)=YMP(I)
              IF (I.LT.NXMP) GO TO 06041
      C
      06050 NXMP=NXM
      C
              DO 16000 I=1,NXM
                  XMP(I)=XM(I)
                  YMP(I)=YM(I)
      16000 CONTINUE
      C
              GO TO 01000
              END
```

```
C
C*****************************************************************)
C
C **** SUBROUTINE PTRA DETERMINES SCREEN PLOTTING POINTS
C
      SUBROUTINE PTRA(IX,IY,XP,YP)
      DIMENSION D(48,48)
      COMMON D,XSC,YSC,ZSC,CA1,SA1,CA2,SA2,NX,NY,FOC,DIS,XV,YV
      X=XSC*(IX-1.)
      Y=YSC*(IY-1.)
      Z=ZSC*D(IX,IY)
      W=X*SA1+Y*CA1
      S0=W*CA2+DIS+FOC
      XI=X*CA1-Y*SA1
      YI=W*SA2+Z*CA2
      IF (FOC.EQ.0.) GO TO 01000
      XP=XI/(S0/FOC-1.)-XV
      YP=YI/(S0/FOC-1.)-YV
      GO TO 01010
01000 XP=(XI-XV)*DIS
      YP=(YI-YV)*DIS
01010 RETURN
      END
```

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ORIGINAL PAGE IS
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```
      C
      C*****************************************************************************)
      C
      C **** SUROUTINE DIAG FIGURES OUT SOMETHING BUT I DON'T KNOW WHAT
      C
            SUBROUTINE DIAG(IX,IY,INDG)
            DIMENSION D(48,48)
            COMMON D,XSC,YSC,ZSC,CA1,SA1,CA2,SA2,NX,NY
      C
            CEN=0.
            NCEN=0
            IF (IX.LE.1) GO TO 01010
            IF (IY.LE.2) GO TO 01000
            CEN=CEN+1.5*D(IX,IY-1)-.5*D(IX-1,IY-2)
            NCEN=NCEN+1
      01000 IF (IY.GE.NY) GO TO 01020
      C
            CEN=CEN+1.5*D(IX,IY)-.5*D(IX-1,IY+1)
            NCEN=NCEN+1
      01010 IF (IX.GE.(NX+1)) GO TO 01030
      C
            IF (IY.GE.NY) GO TO 01020
            CEN=CEN+1.5*D(IX+1,IY)-.5*D(IX+2,IY+1)
            NCEN=NCEN+1
      01020 IF (IX.GE.(NX+1)) GO TO 01030
      C
            IF (IY.LE.2) GO TO 01030
            CEN=CEN+1.5*D(IX+1,IY-1)-.5*D(IX+2,IY-2)
            NCEN=NCEN+1
      01030 CEN=CEN/NCEN
      C
            DC1=.5*(D(IX,IY)+D(IX+1,IY-1))
            DC2=.5*(D(IX,IY-1)+D(IX+1,IY))
            IF (ABS(CEN-DC1).GE.ABS(CEN-DC2)) GO TO 01040
            INDG=1
            RETURN
      01040 INDG=0
      C
            RETURN
            END
```


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```
C
C**********************************************************************)
C
C **** SUBROUTINE DIN INITIALIZES ALL SORTS OF PLOTTING PARAMETERS
C
      SUBROUTINE DIN
      DIMENSION D(48,48),NAR(2304)
      COMMON D,XSC,YSC,ZSC,CA1,SA1,CA2,SA2,NX,NY
      COMMON /FILE/ VECMUL
C
90000 FORMAT(16H1BAD DATA NERR =,I2)
90010 FORMAT(4I5,F10.5)
90020 FORMAT(2I5,3F10.5)
90030 FORMAT(14H1ILLEGAL ANGLE)
90040 FORMAT(17H1WRONG SIZE ARRAY)
90050 FORMAT(26H1BAD COMPRESSION PARAMETER)
90060 FORMAT(17H1ILLEGAL ROTATION)
90070 FORMAT(16H1BAD PLOT LIMITS)
90080 FORMAT(40H1COMPRESSED ARRAY TOO LARGE OR TOO SMALL)
C
      NRN = 48
      NCH = 48
      CALL CREAD(NAR,NCH,NRN,NERR)
      NCH=NRN*NCH
      IF (NERR.EQ.0) GO TO 01000
      TYPE 90000,NERR
      STOP
C
01000 DO 10000 I=1,2
        READ(1,90010) NYIN,NYI,NYF,NCY,YSC
        IF (NYI) 10010,10020,10030
10010   TYPE 90070
        STOP
C
10020   NYI=1
10030   IF (NYF) 10010,10040,10050
10040   NYF=NYIN
10050   IF (NYI.GE.NYF) GO TO 10010
        IF (NYF.GT.NYIN) GO TO 10010
        IF (NCY) 10060,10070,10080
10060   TYPE 90050
        STOP
C
10070   NCY=(NYF-NYI+48)/48
10080   NY=(NYF-NYI+1)/NCY
        IF (NY.GT.6) GO TO 10100
10090   TYPE 90010
        STOP
C
10100   IF (NY.GT.48) GO TO 10090
        IF (I.GT.1) GO TO 10000
        NXIN=NYIN
        NXI=NYI
        NCX=NCY
        NX=NY
        XSC=YSC
```

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```
      10000 CONTINUE
      C
            IF (XSC.LE.0.) GO TO 01100
            IF (YSC.GT.0.) GO TO 01110
      01100 XSC=1.
            YSC=(NY-1.)*NCY/((NX-1.)*NCX)
      01110 IF (NCH.EQ.NXIN*NYIN) GO TO 01120
            TYPE 90040
            STOP
      C
      01120 READ(1,90020) LGIN,NROT,AL1,AL2,ZSC
            IF (ZSC.GT.0.) GO TO 01130
            ZSC=XSC
      C
      01130 DO 11000 J=1,NY
                DO 11000 I=1,NX
                NT=0
                IP=NXI-1+(I-1)*NCX+(NYI-1+(J-1)*NCY)*NXIN
      C
                DO 12000 JC=1,NCY
                   DO 12000 IC=1,NCX
                      NT=NT+NAR(IP+IC+NXIN*JC-NXIN)
      12000     CONTINUE
      C
                NAR(I+NX*J-NX)=NT
      11000 CONTINUE
      C
            IF (((AL1-85.)*(AL1-5.)).LE.0.) GO TO 01150
      01140 TYPE 90030
            STOP
      C
      01150 IF (((AL2-85.)*(AL2-5.)).GT.0.) GO TO 01140
            AL1=AL1/57.29578
            CA1=COS(AL1)
            SA1=SIN(AL1)
            AL2=AL2/57.29578
            CA2=COS(AL2)
            SA2=SIN(AL2)
            IF (NROT*(NROT-3).LE.0) GO TO 02000
            TYPE 90060
            STOP
      C
      02000 IF (NROT.LE.0) GO TO 02010
            IF (NROT-2) 02020,02030,02040
      C
      02010 IP1=1
            IP2=NX
            IP3=-NX
            GO TO 03000
      C
      02020 NT=NX
            NX=NY
            NY=NT
            SCT=XSC
            XSC=YSC
            YSC=SCT
```

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```
              IP1=-NY
              IP2=1
              IP3=NX*NY
              GO TO 03000
        C
        02030 IP1=-1
              IP2=-NX
              IP3=NX+NX*NY+1
              GO TO 03000
        C
        02040 NT=NX
              NX=NY
              NY=NT
              SCT=XSC
              XSC=YSC
              YSC=SCT
              IP1=NY
              IP2=-1
              IP3=1
        C
        03000 ZMAX=0.
              IF (LGIN.GT.0) GO TO 03010
        C
              DO 20000 IX=1,NX
                  DO 20000 IY=1,NY
                      IP=IP1*IX+IP2*IY+IP3
                      DT=NAR(IP)
                      D(IX,IY)=DT
                      IF (DT.LE.ZMAX) GO TO 20000
                      ZMAX=DT
        20000 CONTINUE
        C
              GO TO 04000
        C
        03010 ZMIN=LGIN
              ZMIN=ALOG10(ZMIN)
        C
              DO 30000 IX=1,NX
                  DO 30000 IY=1,NY
                      IP=IP1*IX+IP2*IY+IP3
                      IF (LGIN.LT.NAR(IP)) GO TO 30010
                      D(IX,IY)=0.
                      GO TO 30000
        30010         DT=NAR(IP)
                      DT=ALOG10(DT)-ZMIN
                      D(IX,IY)=DT
                      IF (DT.LE.ZMAX) GO TO 30000
                      ZMAX=DT
        30000 CONTINUE
        C
        04000 ZSC=ZSC*(NX-1.)/(XSC*ZMAX)
              YSC=YSC*(NX-1.)/(XSC*(NY-1.))
              XSC=1.
              YMAX=10./(NX-1)
              XSC=XSC*YMAX
              YSC=YSC*YMAX
```

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```
      ZSC=ZSC*YMAX
      RETURN
      END
```

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```
      C*****************************************************************)
      C
      C        **** JBRKC - CALLS JBRKFN TO FIND CURRENT DENSITY
      C        **** OF THE BIRKELAND CURRENT MODEL DEFINED BY
      C        **** CURDIS AT POINTS ON A SPHERE OF RADIUS "ALT"
      C        **** GREATER THAN THAT OF THE EARTH'S.
      C
      C*****************************************************************)
      C
            COMMON /FILE/ CL1,CL2,NUMT,NUML,RF,TP(4,6,72),AMPS(2,5,72),
           1RZF(2,6),RB(2,6),RT(2,6),RZI(5),RZE(5),REJ(5),RI(2,5),
           2SCL(2,6),CCL(2,6),SMU(2,6),CMU(2,6)
            DATA RE / 6371000. /
            DATA PI / 3.14159265 /
            DATA ALTI / 140000. /
      C
            ALT = 450000.
      C
            OPEN (UNIT=1,NAME='DIS.DAT',TYPE='OLD')
            READ (1,*) NCODE, DF
            READ (1,*) CL1, CL2
            READ (1,*) NUMT, NUML
            N = NUMT + 1
            READ (1,*) (((TP(I,J,K), K=1,NUML), J=1,N), I=1,4)
            READ (1,*) (((AMPS(I,J,K), K=1,NUML), J=1,NUMT), I=1,2)
            READ (1,*) ((RZF(I,J), J=1,N), I=1,2)
            READ (1,*) ((RB(I,J), J=1,N), I=1,2)
            READ (1,*) ((RT(I,J), J=1,N), I=1,2)
            READ (1,*) (RZI(I), I=1,NUMT)
            READ (1,*) (RZE(I), I=1,NUMT)
            READ (1,*) (REJ(I), I=1,NUMT)
            READ (1,*) ((RI(I,J), J=1,NUMT), I=1,2)
            READ (1,*) ((SCL(I,J), J=1,N), I=1,2)
            READ (1,*) ((CCL(I,J), J=1,N), I=1,2)
            READ (1,*) ((SMU(I,J), J=1,N), I=1,2)
            READ (1,*) ((CMU(I,J), J=1,N), I=1,2)
            CLOSE (UNIT=1)
      C
            OPEN (UNIT=2,NAME='DR0:JFIL.DAT',TYPE='NEW',
           1ACCESS='DIRECT',RECORDSIZE=1)
      C
            WRITE (2'1) ALT
            DO 1 ID = 1, 50
               GM = -(ID*80./49. - 40. - 80./49.)*PI/180.
               SGM = SIN(GM)
               CGM = COS(GM)
      C
               DO 1 IE = 1, 50
                  GC = (IE*80./49. - 40. - 80./49.)*PI/180.
                  SGC = SIN(GC)
                  CGC = COS(GC)
                  XL = (RE + ALT)*CGC*SGM
                  YL = (RE + ALT)*SGC
                  ZL = (RE + ALT)*CGC*CGM
                  BRA = FUN(XL,YL,ZL)
      12          IT = 1 + IE + (ID - 1)*50
```

```
          WRITE (2'IT) BRA
    1     CONTINUE
          CLOSE (UNIT=2)
          STOP
          END
```


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```
0001          FUNCTION FUN(XL,YL,ZL)
        C
        C**********************************************************************)
        C
        C **** JBRKFN CALCULATES CURRENT DENSITY IN F-A CURRENTS
        C
        C**********************************************************************)
        C
0002          DIMENSION RM(3,3), FAMP(6,72)
0003          COMMON /FILE/ CL1,CL2,NUMT,NUML,RF,TP(4,6,72),AMPS(2,5,72),
             1RZF(2,6),RB(2,6),RT(2,6),RZI(5),RZE(5),REJ(5),RI(2,5),
             2SCL(2,6),CCL(2,6),SMU(2,6),CMU(2,6)
0004          REAL*4 LAMBDA, MP, JT
0005          DATA RE / 6371000. /
0006          DATA ALTI / 140000. /
0007          DATA PI / 3.14159265 /
        C
0008          N = NUMT + 1
        C
0009          JT = 0.
0010          I = NUMT + 1
0011          DO 10 M = 1,2
0012             IF (M.EQ.2) I = NUMT
0013             DO 10 N = 1, I
0014                DO 10 J = 1, NUML
0015                   IF (M.EQ.2) GO TO 12
0016                   FAMP(1,J) = AMP(1,1,J)
0017                   FAMP(NUMT+1,J) = -AMP(1,NUMT,J)
0018                   IF(N .EQ. (NUMT+1)) GO TO 11
0019                   IF(N .GT. 1) FAMP(N,J) = AMP(1,N,J) - AMP(1,N-1,J)
0020                   IF(FAMP(N,J) .EQ. 0.) GO TO 10
0021                   GO TO 11
0022    12             FAMP(N,1) = AMP(2,N,NUML) - AMP(2,N,1)
0023                   IF (J.GT.1) FAMP(N,J) = AMP(2,N,J-1) - AMP(2,N,J)
0024                   IF (FAMP(N,J).EQ.0.) GO TO 10
0025    11             LAMBDA = 2.*(J-.5)*PI/NUML
0026                   IF (M.EQ.2) LAMBDA = 2*J*PI/NUML
0027                   SLA = SIN(LAMBDA)
0028                   CLA = COS(LAMBDA)
        C
0029                   RM(1,1) =  CLA*CMU(M,N)
0030                   RM(1,2) =  SLA*CMU(M,N)
0031                   RM(1,3) = -SMU(M,N)
0032                   RM(2,1) = -SLA
0033                   RM(2,2) =  CLA
0034                   RM(2,3) =  0.
0035                   RM(3,1) =  CLA*SMU(M,N)
0036                   RM(3,2) =  SLA*SMU(M,N)
0037                   RM(3,3) =  CMU(M,N)
        C
0038                   XF = XL*RM(1,1) + YL*RM(1,2) + (ZL-RZF(M,N))*RM(1,3)
0039                   YF = XL*RM(2,1) + YL*RM(2,2) + (ZL-RZF(M,N))*RM(2,3)
0040                   ZF = XL*RM(3,1) + YL*RM(3,2) + (ZL-RZF(M,N))*RM(3,3)
        C
0041                   RCF = XF**2 + YF**2
0042                   RBF = SQRT(RCF + (ZF-RB(M,N))**2)
```

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```
0043                       RTF = SQRT(RCF + (ZF-RT(M,N))**2)
          C
0044                       IF((TP(M,N,J)*RCF1) .GT. 40.) GO TO 10
0045                       JT = FAMP(N,J)*TP(M,N,J)
                    1          /(PI*((COSH(TP(M,N,J)*RCF))**2)) + JT
0046      10     CONTINUE
          C
0047             FUN = JT
          C
0048             RETURN
0049             END
```

```
C*************************************************************************)
C
C **** JBRKP - PLOTS CURRENT DENSITY AS ELEVEN COLOR FIELD
C **** USING DIRECT COMMANDS TO TEKTRONIX 4027
C
C*************************************************************************)
C
            DIMENSION IPOL(8), IPC(3), IPA(14), IV(4)
            INTEGER*4 IDEL
            REAL*4 MAXIN, MAXOUT
            DATA IPA / 170,85,170,85,170,85,170,85,170,85,170,85,170,85 /
            DATA RE/6371000./
            DATA PI/3.14159265/
            DATA RF / 'RF' /
C
10          WRITE (5,100)
100         FORMAT ( ' SELECT COLOR RANGE FACTOR ' )
            READ (5,*) RF
C
            WRITE (5,110)
110         FORMAT ( ' SELECT DELAY BUFFER ' )
            READ (5,*) IDEL
C
            CMAX = 0.
            MAXIN = 0.
            MAXOUT = 0.
            CP1 = 1.
            CP11 = 1.
            CP2 = 1.
            CP21 = 1.
            CP3 = 1.
            CP31 = 1.
            CP4 = 1.
            CP41 = 1.
            CP5 = 1.
C
            OPEN (UNIT=2,NAME='DR0:JFIL.DAT',TYPE='OLD',
     1            ACCESS='DIRECT',RECORDSIZE=1)
C
            READ (2'1) ALT
            DO 200 IA = 2, 2501
               READ (2'IA) C
               CMAX = AMAX1(ABS(C),CMAX)
               MAXIN = AMAX1(C,MAXIN)
               MAXOUT = AMIN1(C,MAXOUT)
200         CONTINUE
C
C           **** DEFINE COLORS
C
            WRITE (5,102)
102         FORMAT (11H !MON 4 H K)
            WRITE (5,103)
103         FORMAT (10H !GRA 1,30)
            WRITE (5,1000)
1000        FORMAT (20H !MAP C0   0,100,100)
            WRITE (5,1001)
```

```
FORTRAN IV-PLUS V02-51E          16:36:09     15-OCT-82              PAGE 2
JBRKP.FTN                /TR:ALL/WR

      1001     FORMAT (20H IMAP C1 180,  50,100)
               WRITE (5,1002)
      1002     FORMAT (20H IMAP C2 140,  50,100)
               WRITE (5,1003)
      1003     FORMAT (20H IMAP C3  80,  50,100)
               WRITE (5,1004)
      1004     FORMAT (20H IMAP C4 220,  50,100)
               WRITE (5,1005)
      1005     FORMAT (20H IMAP C5 300,  40,100)
               WRITE (5,1006)
      1006     FORMAT (20H IMAP C6 330,  40,100)
               WRITE (5,1007)
      1007     FORMAT (20H IMAP C7   0,   0,100)
      C
      C        **** DEFINE PATTERNS
      C
               WRITE (5,2000) IPA
      2000     FORMAT (15H IPAT P0 C0 C0 ,13(I3,1H,),I3)
               WRITE (5,2001) IPA
      2001     FORMAT (15H IPAT P1 C1 C1 ,13(I3,1H,),I3)
               WRITE (5,2002) IPA
      2002     FORMAT (15H IPAT P2 C1 C2 ,13(I3,1H,),I3)
               WRITE (5,2003) IPA
      2003     FORMAT (15H IPAT P3 C2 C2 ,13(I3,1H,),I3)
               WRITE (5,2004) IPA
      2004     FORMAT (15H IPAT P4 C2 C3 ,13(I3,1H,),I3)
               WRITE (5,2005) IPA
      2005     FORMAT (15H IPAT P5 C3 C3 ,13(I3,1H,),I3)
               WRITE (5,2006) IPA
      2006     FORMAT (15H IPAT P6 C4 C4 ,13(I3,1H,),I3)
               WRITE (5,2007) IPA
      2007     FORMAT (15H IPAT P7 C4 C5 ,13(I3,1H,),I3)
               WRITE (5,2008) IPA
      2008     FORMAT (15H IPAT P8 C5 C5 ,13(I3,1H,),I3)
               WRITE (5,2009) IPA
      2009     FORMAT (15H IPAT P9 C6 C6 ,13(I3,1H,),I3)
               WRITE (5,2010) IPA
      2010     FORMAT (16H IPAT P10 C6 C6 ,13(I3,1H,),I3)
      C
      C        **** GRAPH DATA
      C
               DO 300 ID = 1, 52
                  NE = 50
                  IF (ID .GT. 50) NE = 5
                  JY = ID*8 - 4
                  DO 300 IE = 1, NE
                     IF (ID .GT. 50) GO TO 32
                     JX = IE*8
      C
      C        **** DEFINE PIXEL PARAMETERS
      C
                     IPOL(1) = JX - 4
                     IPOL(3) = JX - 4
                     IPOL(5) = JX + 4
                     IPOL(7) = JX + 4
                     IPOL(2) = JY - 4
```

```
                IPOL(4) = JY + 4
                IPOL(6) = JY + 4
                IPOL(8) = JY - 4
C
                GO TO 31
      32        IPOL(1) = 570 + (ID-50)*10
                IPOL(2) = (IE-1)*20 + 21
                IPOL(3) = 570 + (ID-50)*10
                IPOL(4) = IE*20 + 21
                IPOL(5) = 570 + (ID-49)*10
                IPOL(6) = IE*20 + 21
                IPOL(7) = 570 + (ID-49)*10
                IPOL(8) = (IE-1)*20 + 21
C
      31        DO 30 I = 1, IDEL
                   BUF = BUFUN(IDEL)
      30        CONTINUE
C
                IF (ID .GT. 50) GO TO 33
C
C         **** CONDITION DATA - ADJUST DYNAMIC RANGE, CONVERT TO INTEGER
C
                II = 1 + IE + (ID - 1)*50
                READ (2'II) C
                IF (C/CMAX) 34,35,36
      34        IPZ = -INT(ALOG10(-RF*C/CMAX) + .5)
                GO TO 37
      35        IPZ = 0
                GO TO 33
      36        IPZ = INT(ALOG10(RF*C/CMAX) + .5)
      37        IF (ABS(RF*C/CMAX) .LT. 1.) IPZ = 0.
      33        IF (ID .GT. 50) IPZ = ((-1)**(ID-50))*IE
                IF (ID .GT. 50) C = 1.
C
C         **** SET COLOR FOR PIXEL
C
                IF (IPZ) 306,307,301
C
C         **** POSITIVE
C
      301       IF (IPZ .GE. 5) GO TO 305
                GO TO (302,303,304,305), IPZ
      302       WRITE (5,3001)
      3001      FORMAT (8H ICOL P1)
                CP1 = AMIN1(CP1,C)
                GO TO 314
      303       WRITE (5,3002)
      3002      FORMAT (8H ICOL P2)
                CP2 = AMIN1(CP2,C)
                GO TO 314
      304       WRITE (5,3003)
      3003      FORMAT (8H ICOL P3)
                CP3 = AMIN1(CP3,C)
                GO TO 314
      305       WRITE (5,3004)
      3004      FORMAT (8H ICOL P4)
```

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```
                        CP4 = AMIN1(CP4,C)
                        GO TO 314
        306             WRITE (5,3005)
        3005            FORMAT (8H ICOL P5)
                        CP5 = AMIN1(CP5,C)
                        GO TO 314
        C
        C        **** ZERO
        C
        307             WRITE (5,3000)
        3000            FORMAT (8H ICOL P0)
                        GO TO 314
        C
        C        **** NEGATIVE
        C
        308             IF (IPZ .LE. -5) GO TO 313
                        GO TO (309,310,311,312), -IPZ
        309             WRITE (5,3006)
        3006            FORMAT (8H ICOL P6)
                        CP1 = AMIN1(CP1,ABS(C))
                        GO TO 314
        310             WRITE (5,3007)
        3007            FORMAT (8H ICOL P7)
                        CP2 = AMIN1(CP2,ABS(C))
                        GO TO 314
        311             WRITE (5,3008)
        3008            FORMAT (8H ICOL P8)
                        CP3 = AMIN1(CP3,ABS(C))
                        GO TO 314
        312             WRITE (5,3009)
        3009            FORMAT (8H ICOL P9)
                        CP4 = AMIN1(CP4,ABS(C))
                        GO TO 314
        313             WRITE (5,3010)
        3010            FORMAT (9H ICOL P10)
                        CP5 = AMIN1(CP5,ABS(C))
        C
        C        **** SET PIXEL SIZE
        C
        314             WRITE (5,104) IPOL
        104             FORMAT (6H IPOL ,7(I3,1H,),I3)
        C
                        IF (ID .GT. 50) GO TO 300
                        IF ((C .LT. MAXIN) .AND. (C .GT. MAXOUT)) GO TO 300
        C
        C        **** PLOT PIXEL
        C
                        WRITE (5,106) JX,IPOL(4),JX,IPOL(6),IPOL(3),JY,IPOL(5),JY
        106             FORMAT (12H ILIN 2IVEC ,3(I3,1H,),I3,6H IVEC ,3(I3,1H,),I3,
                     1         5H ILIN)
        300      CONTINUE
        C
                 CLOSE (UNIT=2)
        C
        C        **** PLOT LATITUDE CIRCLES AND MLT LINES
        C
```

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```
0170            DO 400 I = 1, 4
0171               DO 40 K = 1, IDEL
0172                  BUF = BUFUN(IDEL)
0173      40       CONTINUE
          C
0174               J = I*50
0175               WRITE (5,4000)
0176      4000     FORMAT (7H |LIN P)
0177               WRITE (5,4001)
0178      4001     FORMAT (17H |VEC 0,0,204,200)
0179               WRITE (5,4002)
0180      4002     FORMAT (7H |LIN E)
0181               WRITE (5,4003) J
0182      4003     FORMAT (6H |CIR ,I3)
0183      400   CONTINUE
          C
0184            WRITE (5,5000)
0185      5000  FORMAT (7H |LIN E)
          C
0186            DO 500 I = 1, 4
0187               DO 50 J = 1, IDEL
0188                  BUF = BUFUN(IDEL)
0189      50       CONTINUE
0190               IV(1) = INT(200*SIN((I-1)*PI/2.) + 204)
0191               IV(2) = INT(200*COS((I-1)*PI/2.) + 200)
0192               IV(3) = INT(50*SIN((I-1)*PI/2.) + 204)
0193               IV(4) = INT(50*COS((I-1)*PI/2.) + 200)
          C
0194               WRITE (5,5001) IV
0195      5001     FORMAT (6H |VEC ,3(I3,1H,),I3)
          C
0196      500   CONTINUE
          C
          C     **** WRITE HEADLINES
          C
0197            WRITE (5,6000)
0198      6000  FORMAT (18H |WOR|MAR 64|UP 28)
0199            WRITE (5,6001) ALT
0200      6001  FORMAT (/8H DENSITY/3H OF/19H BIRKELAND CURRENTS
               1        //3H AT,1PE8.1,2H M)
0201            WRITE (5,6002) MAXIN, MAXOUT
0202      6002  FORMAT (///8H |ATT C3/10H MAXIN  = ,1PE8.1,7H A/M**2/
               1        8H |ATT C6/10H MAXOUT = ,1PE8.1,7H A/M**2)
0203            WRITE (5,6003) CP5,CP4,CP3,CP2,CP1
0204      6003  FORMAT (14H |ATT C0|DOW 6,5(//3X,1PE8.1,7H A/M**2),5H |MON)
          C
0205            STOP
0206            END
```

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```
C*************************************************************************)
C
C **** PROVIDES A TIME LAG BUFFER FOR PLOTTING ON A 4027
C
C*************************************************************************)
C
      FUNCTION BUFUN(IDEL)
      BUFR = SIN(IDEL/10.)
      BUFUN = TANH(BUFR)
      RETURN
      END
```